FEBRUARY 1981

MDC G9346

NASA CR-
160934

(NASA-CR-160934) SPACE PLATFORM ADVANCED TECHNOLOGY STUDY Final Report (McDonnell-Douglas Astronautics Co.) 75 p HC A04/MF A01 CSCL 22B

N81-20146

Unclas
G3/15 41782

SPACE PLATFORM ADVANCED TECHNOLOGY STUDY

FINAL REPORT

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY

MCDONNELL DOUGLAS
CORPORATION

MCDONNELL DOUGLAS CORPORATION

SPACE PLATFORM ADVANCED TECHNOLOGY STUDY

FINAL REPORT

FEBRUARY 1981

MDC G9346

PREPARED BY:

GENE BURNS
STUDY MANAGER

APPROVED BY:

FRITZ RUNGE
MANAGER ADVANCED
PAYLOAD SYSTEMS

APPROVED BY:

GEORGE BUTLER
DIRECTOR ADVANCED
SPACE PROGRAMS

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY-HUNTINGTON BEACH

5301 Bolsa Avenue Huntington Beach, California 92647 (714) 896-3311

CONTENTS

Section 1
INTRODUCTION

This study was performed under NASA Contract NAS9-16001 for the Johnson Spaceflight Center, Houston, Texas. The work was accomplished within the Advanced Space Programs Directorate of McDonnell Douglas Astronautics Company, Huntington Beach, California. The study consisted of six tasks as defined by Figure 1-1. The percentage indication on the figure opposite each task number represents the percentage of the total effort expended on each of the six tasks.

The purpose of the study was to utilize current and past space platform and power module studies to point the way to areas of development for mechanical devices that would be required for the ultimate implementation of a platform erected and serviced by the Shuttle/Orbiter. The study was performed in accordance with the Study Plan contained in the appendix.

During this study Model Development Laboratory of Irvine, California participated as an MDAC subcontractor in fabricating the mechanical portions of the models. MDAC wishes to acknowledge the contribution of this organization in support of the study.

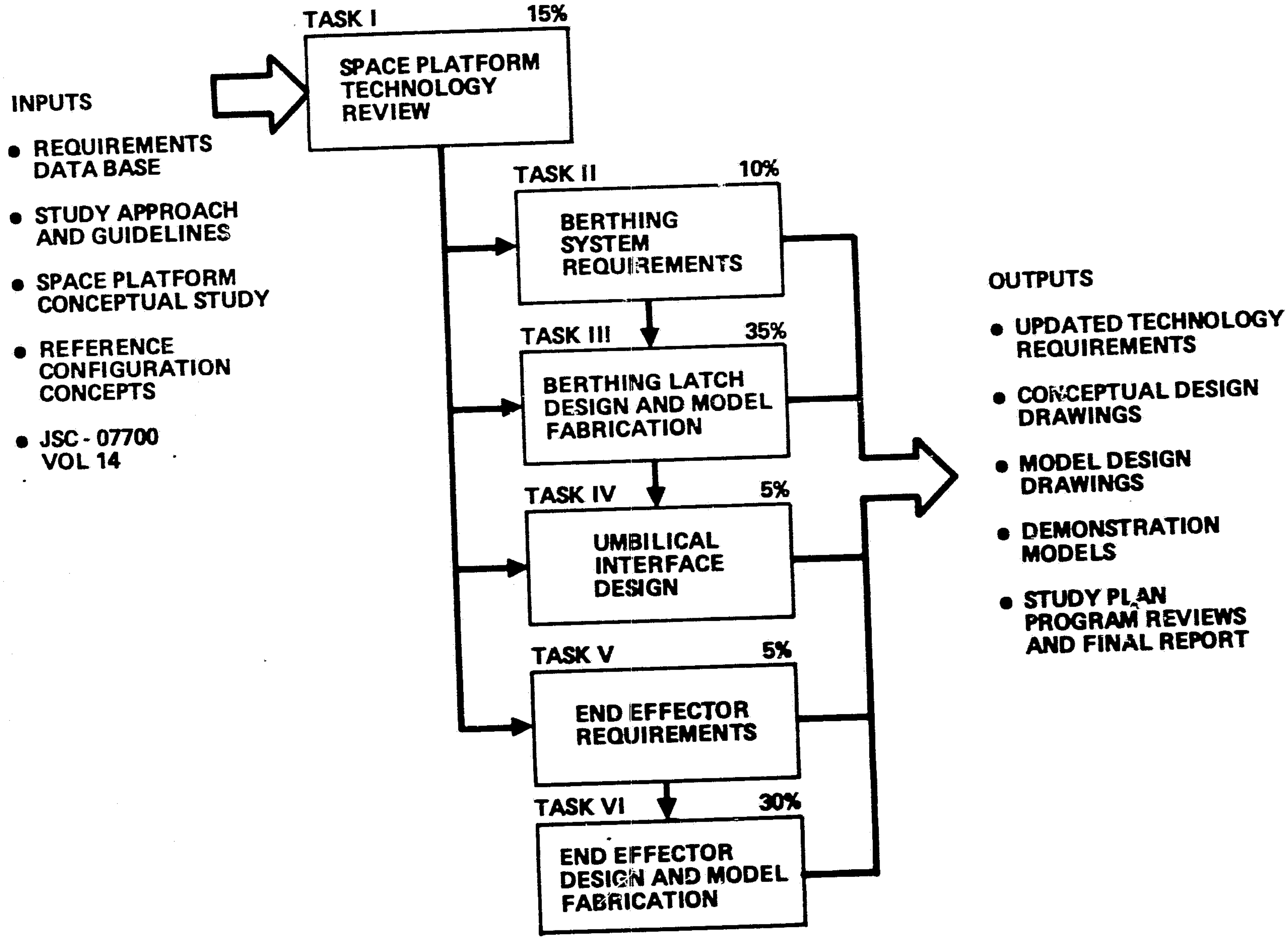


Figure 1-1. Study Task Flow

Section 2
STUDY OBJECTIVES

The objective of the Space Platform Advanced Technology Study is to examine the requirements and partially develop mechanisms which would have application regardless which of many space platform configurations is finally selected to be built. The study consists of six tasks as follows:

- Task I — Space Platform Technology Review
- Task II — Orbiter Berthing System Requirements
- Task III—Berthing Latch Interface Requirements, Design and Model Fabrication
- Task IV — Berthing Umbilical Interface Requirements and Design
- Task V — Adaptive End Effector Requirements
- Task VI — Adpative End Effector Design and Model Fabrication

Task I consisted of reviewing prior studies of Science and Applications Space Platforms, Power Modules, large space structures, and space stations. The objective of this review was to select those mechanical systems, for further development, which would have universal application to platform-type structure buildup in space. The typical space platform will consist of a power system, structural support arms, palletized payloads, gimbals, and potentially pressurized and manned habitability modules. All of these elements must be handled and structurally attached together. They must also provide a variety of functions such as electrical power, communications, and thermal control loops across the mating interfaces. These elements and functions will exist regardless of space platform configuration. Figure 2-1 illustrates a typical space platform orbiting configuration with palletized payloads attached. Because of their universal adaptability, the Orbiter Berthing System, Berthing Latch Interface, Berthing Umbilical Interface, and the Adaptive End Effector for the Orbiter RMS, were selected for further development in Tasks II through V of this study.

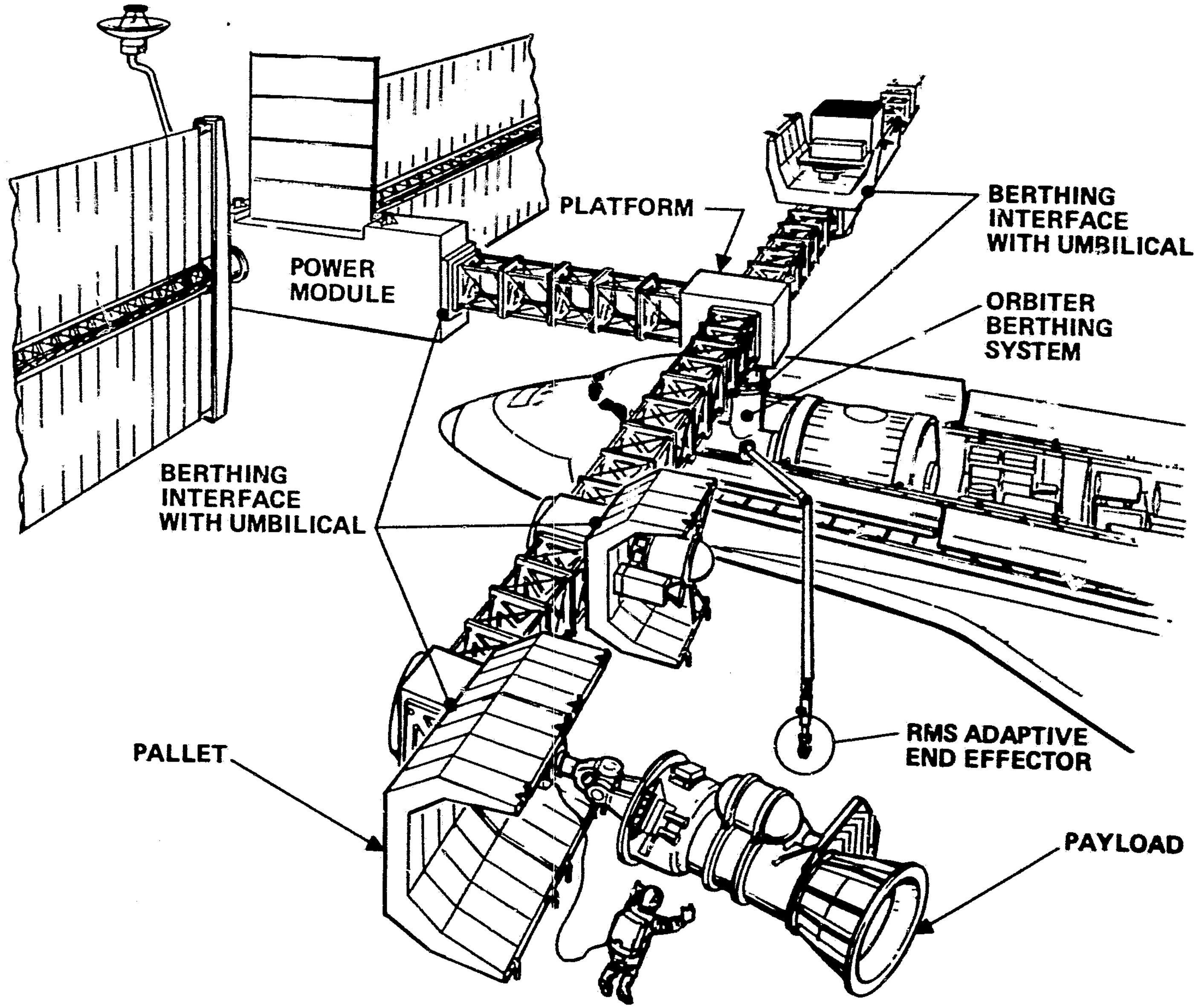


Figure 2-1. Orbiter — Platform — Power Module Berthed Orbiting Configuration

The object of Task II was to establish the requirements for an Orbiter Berthing System. These requirements were derived by analyzing the positioning requirements of the various configuration platforms for deployment servicing and payload changeout. Orbiter bay volume available for stowage of the berthing fixture was defined.

Task III had the objective of developing a full-scale working model of a Berthing Latch Interface Mechanism. In order to accomplish this development the requirements had to be established, a trade study of various mechanism configurations was conducted and a concept selected, design layouts and detail drawings were prepared and a model fabricated.

The requirements for the berthing latch mechanism were derived based on the use of the Orbiter RMS to position and hold the payload in berthing position and to guide the two bodies until a structural latch is accomplished. A total of six Berthing Latch Interface configurations were evaluated and the hexagonal frame configuration was selected based on envelope and lack of mechanical complexity. A full-scale model of the mechanism was designed and fabricated.

Task IV had the objective of establishing requirements for and preparing a preliminary design layout for the umbilical to be used in conjunction with the Orbiter Berthing System and the Berthing Latch Interface mechanism. The requirements were derived based on payload needs, compatibility with the Berthing Latch Interface, and platform requirements. Accommodations were provided for electrical power, data, and coolant fluid transfer across the umbilical interface.

The objective of Tasks V and VI was to develop a full-scale working model of an Adaptive End Effector to be used in conjunction with the Orbiter RMS. The requirements for the end effector were derived based on projected usage in conjunction with future space platform assembly, deployment, maintenance, and payload changeouts. A full-scale working model was fabricated and may be used in conjunction with the RMS simulator at NASA/JSC.

Section 3
STUDY OUTPUTS

3.1 SPACE PLATFORM TECHNOLOGY REVIEW - TASK I

Current and past Science and Applications Space Platform (SASP) studies have evolved many and varied configurations as illustrated by Figure 3-1. It was obvious that this study should select areas of development that are applicable to platform configurations and not a unique feature of a single configuration. The typical SASP will consist of a power system, structural support arms, palletized payloads, gimbals, and potentially pressurized and manned habitability modules. All of these elements must be handled, structurally attached, and provide a variety of functions such as electrical power, communications, and thermal control loops across the interface. A typical example of platform elements is illustrated by Figure 3-2. These elements and functions will exist regardless of platform configuration. As a result of the survey conducted under Task I the Orbiter Berthing System, the Structural and Functional Berthing Interface and the RMS End Effector were selected for development and modeling during this study. These elements have universal application and can be utilized on any platform configuration.

In addition to selecting the items for further development, Task I accomplished the programmatic functions of the study which include preparation of the Study Plan, Schedule, Budget, Monthly Progress Reports, midterm presentation and a final presentation. The Study Plan, containing the schedule, is included the appendix.

3.2 BERTHING SYSTEM REQUIREMENTS LIST - TASK II

The berthing system requirements were derived based on Orbiter constraints, platform interface requirements, and RMS performance.

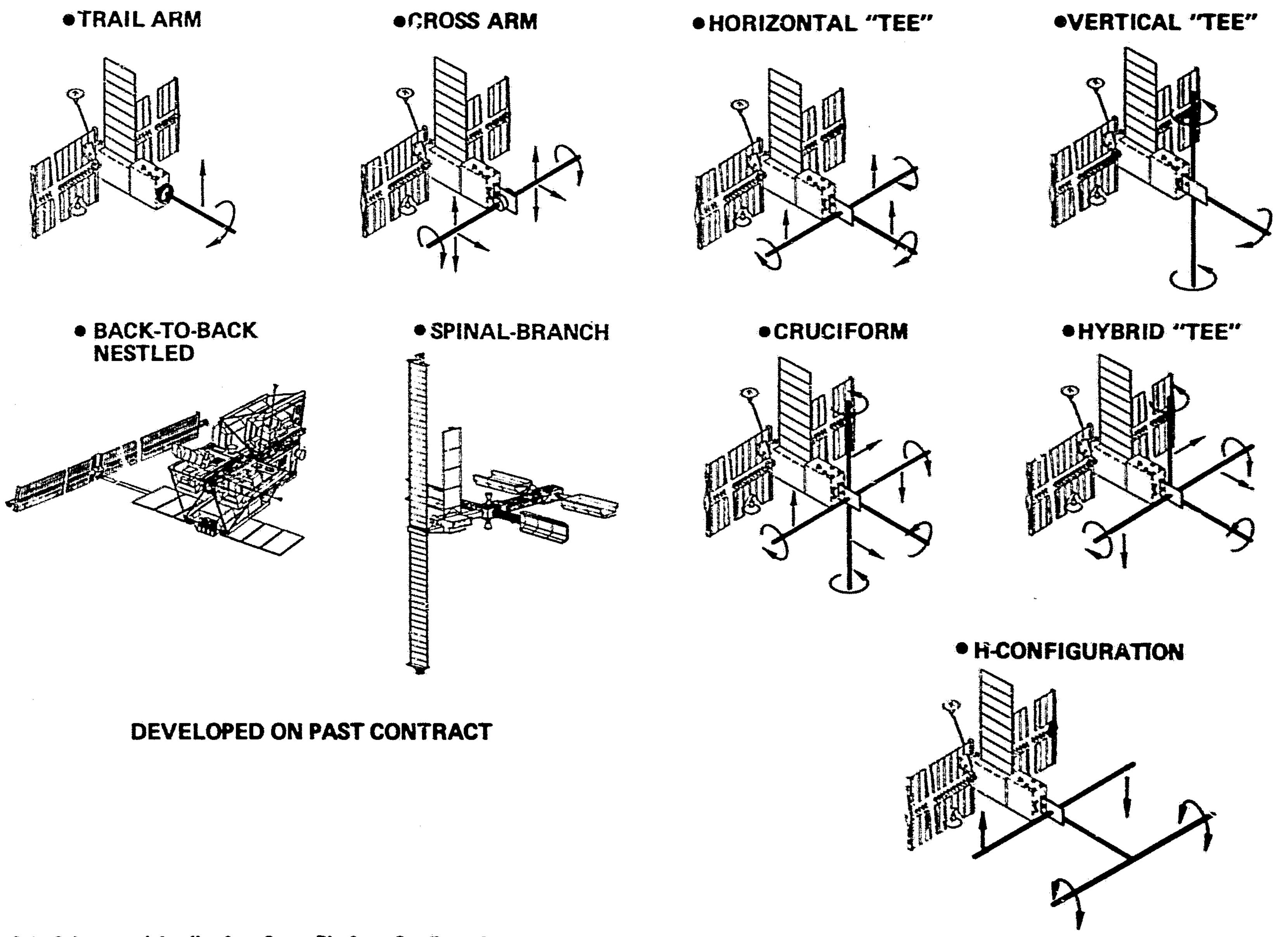


Figure 3-1. Science and Applications Space Platform Configurations Evaluated

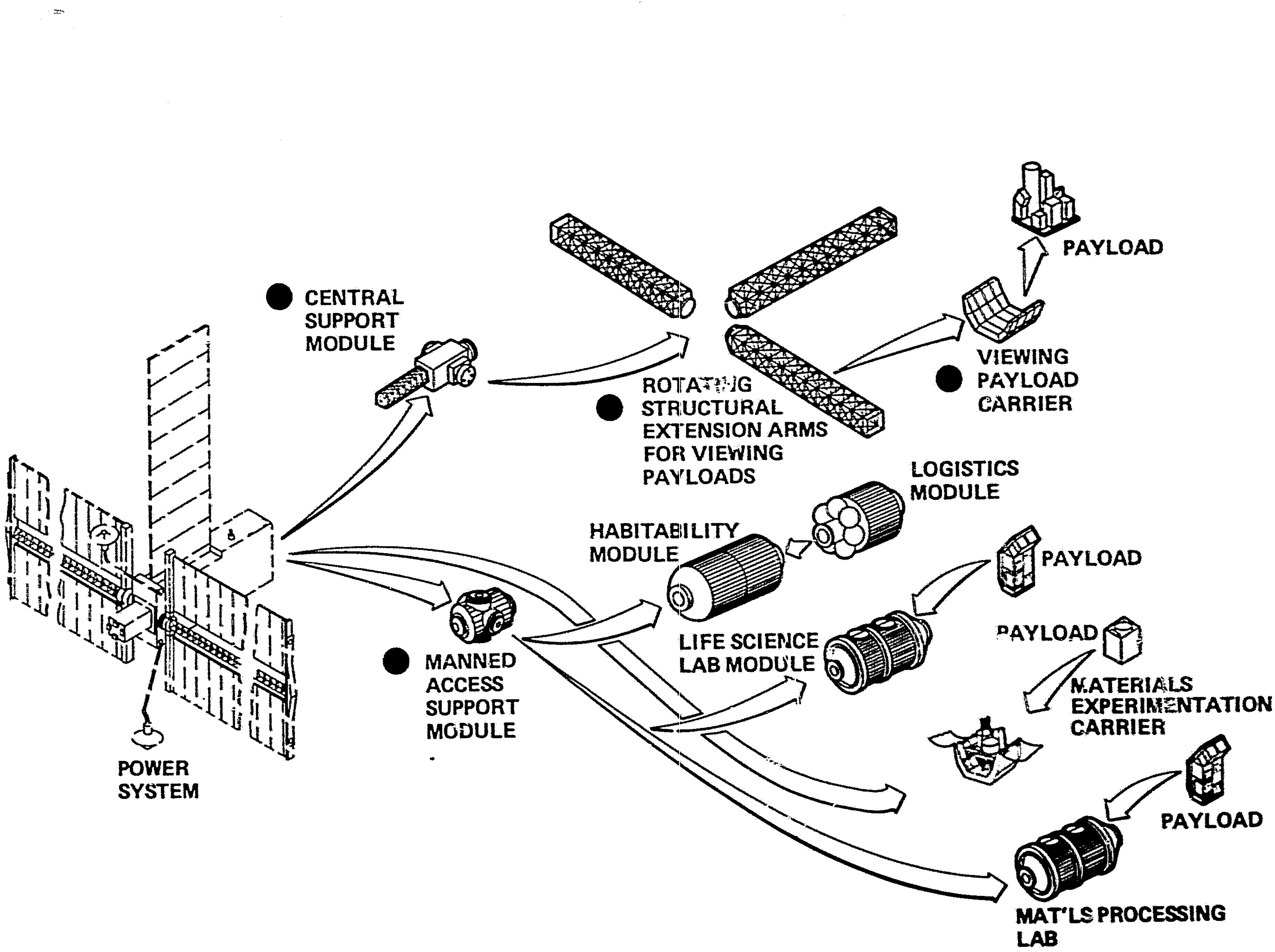


Figure 3-2. Platform Elements

The berthing system must first be designed to be stowed in the cargo bay of the Orbiter. It was established for this study that the berthing system must be compatible with dual MMUs, 90-in. payload envelope, Spacelab module, external airlock, Spacelab short tunnel, and RMS installations. Figure 3-3 illustrates graphically the stowage volume requirements.

The berthing system, in contrast to a docking system, assumes that one side of the interface is attached to the Orbiter and the other side is under control and being positioned by the RMS. Because of the fluidity of platform design and wide variations in mass and Moment of Inertia (MOI), the condition of two Orbiters berthed together was examined to establish load ranges. As illustrated by Figure 3-4 the interface moment produced from the RCS system would be 44,775 ft-lb. The interface moment produced by berthing the two Orbiters, with an impact velocity of 0.1 ft/sec and a structural spring constant of 3.46×10^6 ft-lb/radian, would be 15,469 ft-lb. For the purposes of this study and preliminary design, an interface moment of 16,000 ft-lb in pitch and yaw was selected.

The platform studies assume that during the period when the Orbiter and platform are berthed, the stabilization of the pair will be accomplished by the platform using CMGs. The control system frequency response dictates that structural natural frequencies should be above 0.1 Hz. Figure 3-5 shows that as the platform MOI increases the structural natural frequency becomes almost constant for a given spring rate. The structural stiffness for the berthing system was established at 4×10^6 ft-lb/radian which maintains the structural natural frequency above 0.1 Hz for any platform regardless of MOI. The MOI of 17.62×10^6 slug ft^2 represents two Orbiters berthed together.

Following is a listing of the requirements derived for the berthing system. The key requirements are noted with an asterisk and indicate significant issues in the design of the system.

1. Object — Provide a berthing interface and a structural bridge between the Orbiter and a free-flying space platform or a power module.

* 2. Stowage volume — The berthing system will be installed in the forward portion of the Orbiter cargo bay and be compatible with the

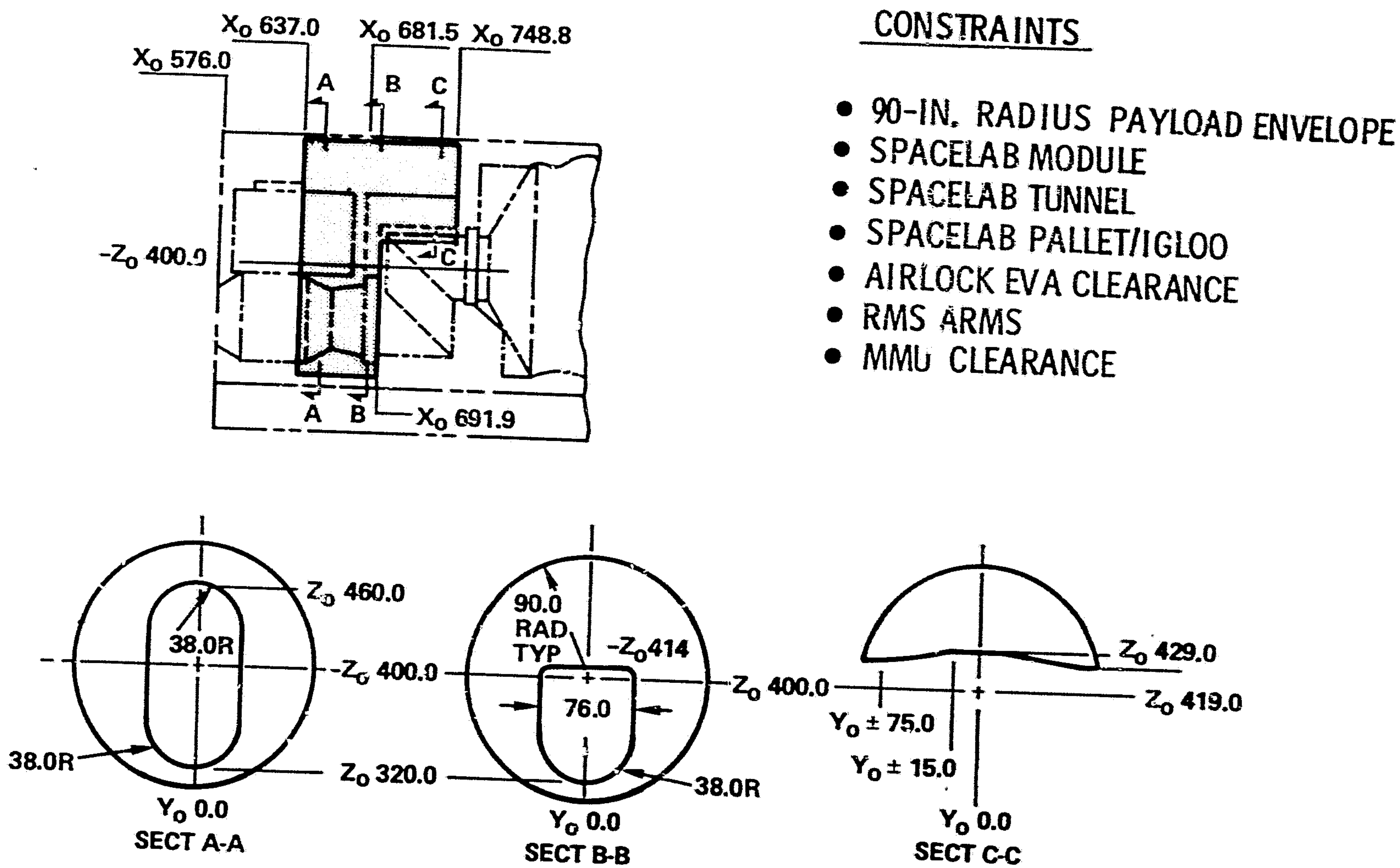
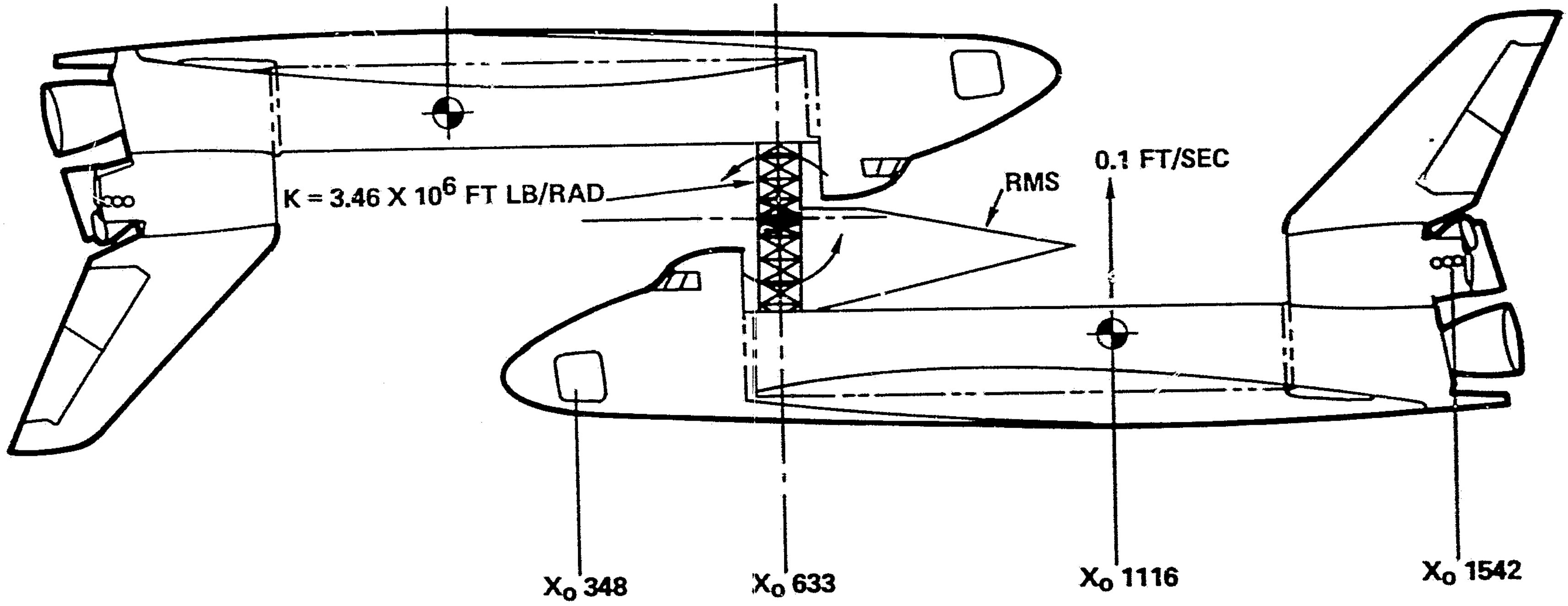


Figure 3-3. Berthing System Stowed Maximum Dynamic Envelope



PITCH TORQUE RCS (ONE FWD AND AFT)	44,775 FT LB
PITCH TORQUE VRCS (ONE FWD AND AFT)	1,243 FT LB
PITCH TORQUE IMPACT CLOSING AT 0.1 FT/SEC	15,469 FT LB

Figure 3-4. Berthing System Loads

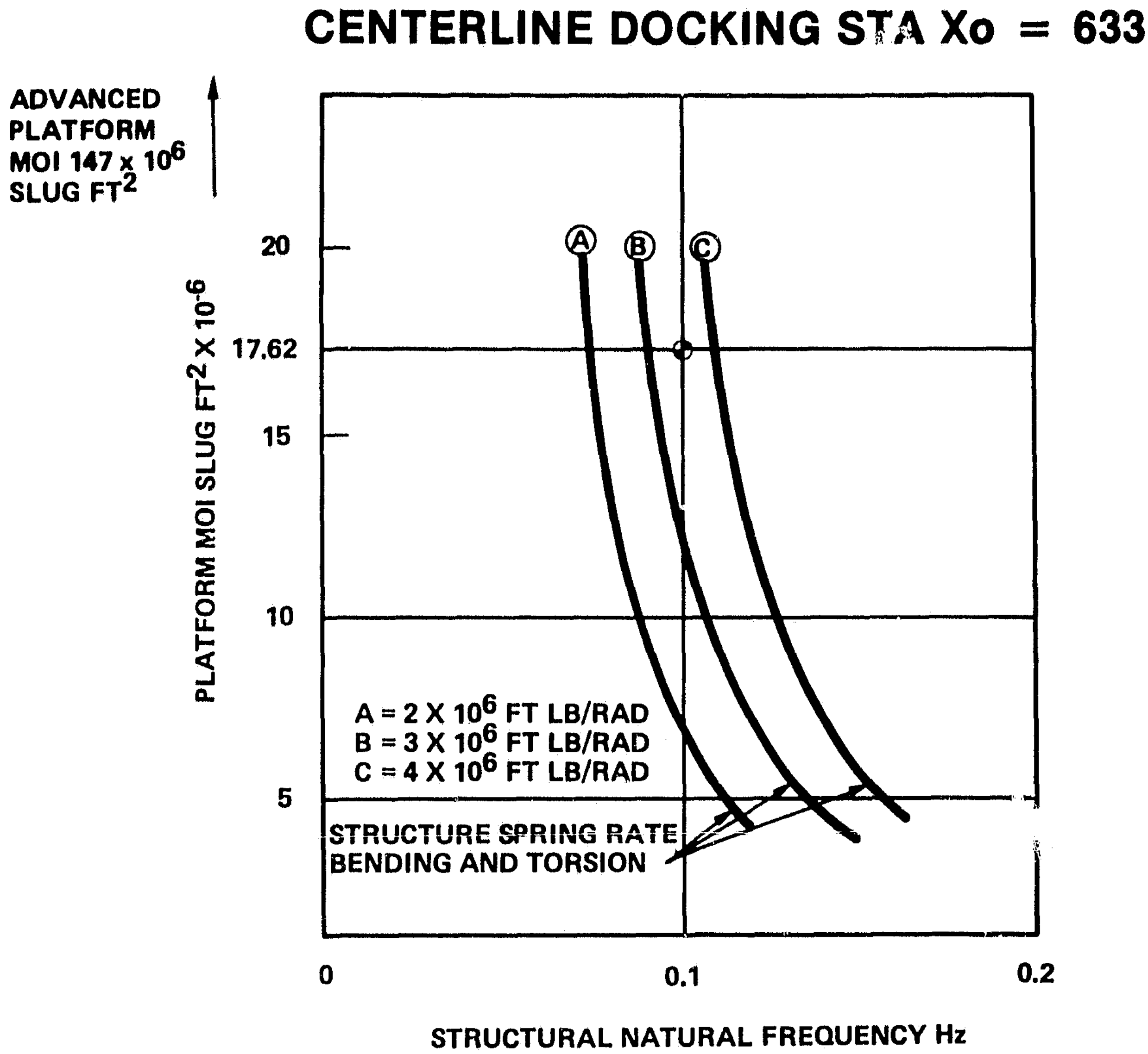


Figure 3-5. Structural Natural Frequency Versus Platform MOI

installation of Spacelab module, short access tunnel, airlock, MMU, Ku-band antenna and left- and/or right-hand installation of RMS.

* 3. Deployed berthing interface — The berthing system will deploy from the Orbiter bay and provide the structural mounting for a berthing latch mechanism. The centerline of the deployed interface will be located at $Y_o = 0$, $Z_o = 515$ minimum, $X_o = 633$ maximum.

4. Orbiter structural interface — The berthing system will structurally attach to the Orbiter through the use of standard Orbiter keel and longeron bridge fittings attach points.

* 5. Structural stiffness – The structural stiffness of the berthing system will be 4×10^6 ft-lb/radian in both bending and torsion. In the deployed position the system will exhibit no looseness or backlash in joints or drive actuators.

* 6. Structural loads – The structural design bending and torsion loads applied at the berthing interface mechanism will be 16,000 ft-lb.

7. Deployment rate – The berthing system will be deployed or stowed in 10 minutes maximum.

8. EVA egress – The berthing system either deployed or stowed will not interfere with EVA egress from the Orbiter airlock.

9. Redundancy – All drive mechanisms and latches will incorporate redundant power sources arranged so that any failure of one will allow operation of the other. Reduced performance in the single failure mode is acceptable.

10. Manual override – All drive mechanisms and latches will incorporate the ability to be operated manually by an EVA astronaut in the event of failure of the power sources.

11. Jettison – A system will be provided to jettison those portions of the berthing system that when deployed would prevent Orbiter cargo bay door closure.

12. Position indication – Instrumentation in the form of switches will be provided to signal when the berthing system is fully deployed and fully stowed.

13. TV and lights – The berthing system will provide a TV camera and lights to illuminate and provide visual berthing guidance to the target vehicle.

14. Electrical power transfer – The berthing system will transfer electrical power to or from an umbilical at the berthing interface to or from interfaces with the three Orbiter primary buses. The electrical power wiring will consist of three circuits each with the capacity for 8 kW at 28 to 33 VDC.

15. Data transfer – The berthing system will transfer data to or from an umbilical at the berthing interface to or from a fixed interface in the Orbiter cargo bay. The data circuits will consist of the following:

    a. Payload scientific data at rates to 5 MBPS

b. Control and display functions (20 circuits)
c. Caution and warning (two circuits)
d. Bidirectional data bus (1.024 MHz)
e. Hardware command circuit (1 kBPS)
f. Telemetry (4 kBPS).

16. Coolant fluid transfer — The berthing system will transfer to and from an umbilical at the berthing interface to a fixed interface in the Orbiter cargo bay. Two coolant circuits (four lines) will be provided. Each line will be capable of flowing 2,175 lb/hr of Freon 21 with a pressure drop of 5 psi maximum.

17. Berthing system controls — The extension and retraction of the berthing system is to be controlled from the RMS operator's station. The controls are to be located on the RMS display and control panel A8. Camera and light controls are to be located on panel A7.

18. Berthing system weight — The weight of the berthing system will not exceed 700 lb including all attachment provisions, the active half of the berthing latch interface, the active half of the umbilicals and the scar weight required for Orbiter bay interfaces.

3.3 BERTHING LATCH INTERFACE MECHANISM (BLIM) REQUIREMENTS AND DESIGN--TASK III

Although the requirements for the BLIM were based on a berthing operation, i.e., RMS-controlled, the implementation of these requirements into a design concept did not lose sight of the potential of the BLIM being used for a docking interface.

Contact velocities and mismatch are based on RMS performance. The one-meter clear access requirement is derived from future potential use on habitability modules. The envelope for the passive half is established by the geometry of a standard pallet. The pallet to platform interface potentially will use the highest number of BLIMs; therefore, it is mandatory that the mechanism design be compatible with a standard Spacelab pallet. Many SASP concepts use the bottom of the pallet as the berthing interface. Therefore half of the BLIM must be compatible with the volume available when the pallet is stowed in the Orbiter bay. Figure 3-6 illustrates the volume restriction to which the berthing mechanism must conform.

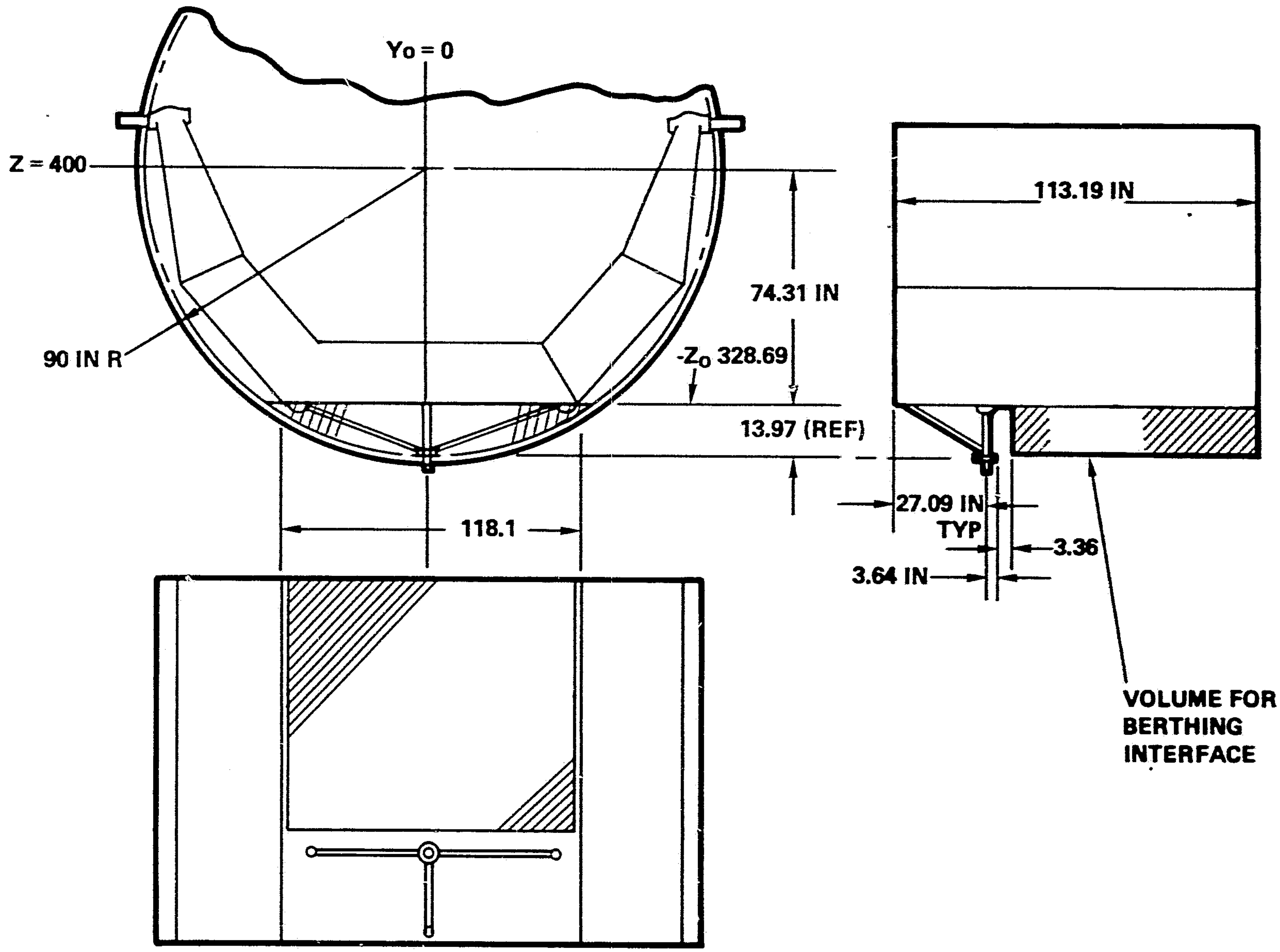


Figure 3-6. Pallet Berthing Interface Envelope

Following is a listing of the requirements derived for the BLIM. The key requirements are noted with an asterisk and indicate significant issues in the design of the mechanism.

1. Object – Capture and structurally attach together two bodies in space, one of which is being maneuvered by the RMS; the other is fixed to the Orbiter.

* 2. Contact velocities – Closing 0.1 ft/sec lateral and forward; 1 deg/sec pitch, roll, and yaw.

* 3. Mismatch – Lateral 4 in.; Angular pitch, roll and yaw 10 deg.

* 4. Clear access – A clear access opening 1.0-meter diameter will be provided through the center of the berthing latch interface mechanism (BLIM).

* 5. Envelope – The envelope for the passive half and the active half of the BLIM will be defined separately. The physical size limits of the passive half are defined by the pallet cargo bay clearance.

6. Loads – The BLIM will be designed for a thrust load in both directions of 20,000 lb and moments in pitch, roll and yaw of 16,000 ft lb. These loads will be applied both in the capture mode and the rigidized mode.

*7. Alignment – After mating and rigidizing any active and passive halves of the BLIM, the angular alignment in pitch, roll, and yaw of one half relative to the other will be within ±1.32 arc min.

8. Capture latches – The capture latches will be designed for simultaneous operation, i.e., a single capture latch of a multiple array of latches will not provide a structural tie between the two halves of the BLIM until all latches are engaged.

9. Umbilicals – The BLIM will provide mounting provisions for two fixed umbilical plates on the passive side of the mechanism and two actuated plates on the active side of the mechanism.

10. Mechanism arrangement – The BLIM will have one active side and one passive side. No electrical signal or power transfer will be required on the passive side of the interface to capture, ridigize, or release the two sides. The BLIM will be designed to allow two active sides to mechanically mate.

11. Control and feedback — The mechanism will contain switches to operate indicator circuits within the Orbiter control station. These circuits will indicate when the active side of the BLIM is:
    a. Ready to berth
    b. Capture complete
    c. Structure latches secure

    The controls for operation of the BLIM are to be located on the RMS display and control panel A8.
12. Redundancy — All drive mechanisms and latches will incorporate redundant power sources arranged so that any failure of one will allow operation of the other. Reduced performance in the single failure mode is acceptable.
13. Manual override — All drive mechanisms will incorporate a feature to allow them to be manually operated by an EVA astronaut in the event of failure of the power sources.
14. Weight — The weight of the active half of the BLIM including controls will not exceed 200 lb. The weight of the passive half will not exceed 50 lb.
15. Operating power — The active half of the BLIM will operate using 28-33 VDC electrical power. The peak electrical power for operation will not exceed 1,000 watts. The steady-state electrical power either mated or unmated will be zero watts.

Prior to selecting the BLIM configuration to be used for design and modeling, six configurations were evaluated. Figure 3-7 illustrates the six configurations. Each configuration was judged based on ability to meet the requirements plus other features such as development status, mechanical complexity, tolerance sensitivity, and envelope. Configuration 6 was ultimately selected because it was the only configuration which could meet the envelope requirement together with the 1-meter clear opeing through the center.

Figure 3-8 illustrates soft scale models which were fabricated of the selected BLIM configuration in order to evaluate clearance in the Orbiter payload bay when the BLIM was installed on a pallet.

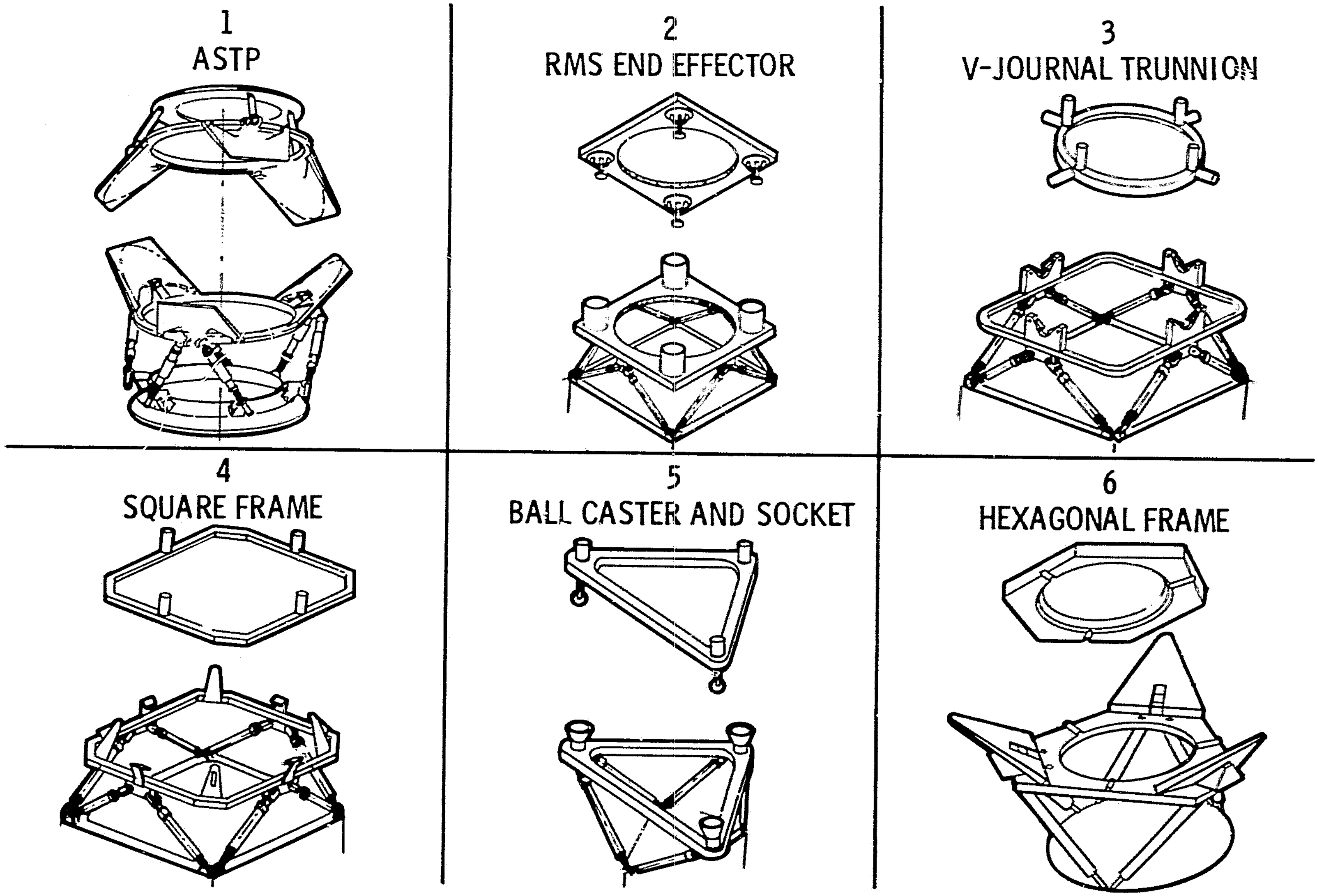
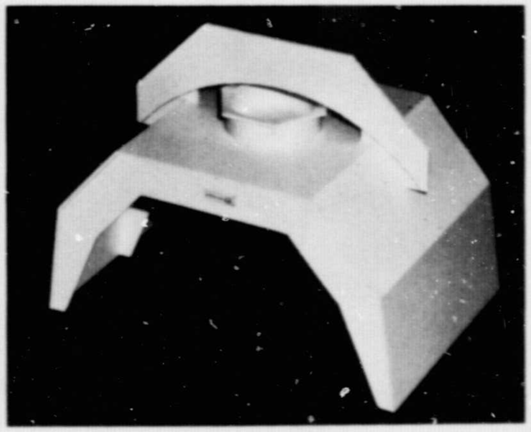
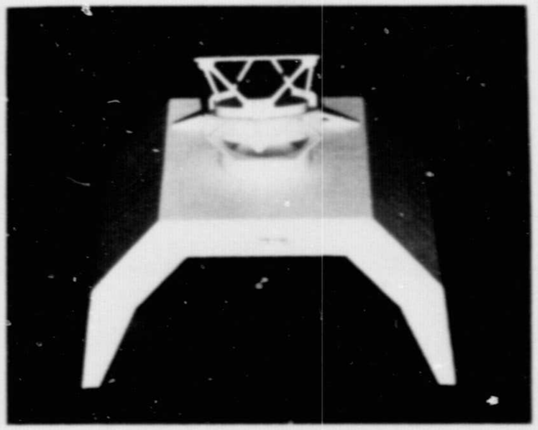


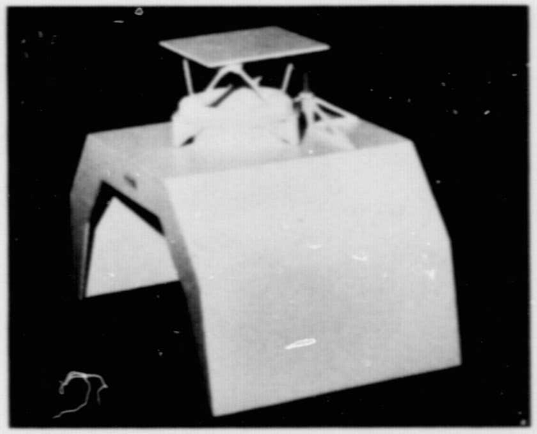
Figure 3-7. Berthing Latch Interface Configurations Evaluated



ORBITER PAYLOAD
BAY CLEARANCE
WITH INACTIVE
SIDE OF BLIM



ACTIVE AND PASSIVE
SIDES ENGAGEMENT



BERTHED AND LATCHED

Figure 3-8. Standard Pallet With Model of Berthing Latch Interface Mechanism Installed

Figure 3-9 illustrates the selected BLIM configuration. The passive half of the BLIM consists of a simple hexagonal frame with three alignment grooves in the face. The active side of the BLIM consists of a hexagonal frame with three alignment keys to match the grooves in the passive frame. On three sides triangular capture guides provide guidance for the passive frame to be nested with the active frame. Contoured within the capture guide is the capture and structure latch mechanism.

Solenoids in each latch are activated by proximity switches in the face of the active frame. The actuation of the solenoids release the capture/structural latches to contain and hold the passive frame. Dual motor actuators retract the latches to provide structural rigidity and alignment. The frames are structurally supported by six struts. These struts are rigid for berthing but can be exchanged for shock struts if energy attenuation is required. The shock struts would contain latches to rigidize them after capture.

Figure 3-10 shows the mechanism in three states--ready, capture, and structure latch. In the ready position the spring-loaded latch is retracted below the surface of the capture guide. When the passive frame activates three or more of the six proximity switches, the frame is within the capture range of the latches. The capture solenoids are actuated and the latches driven by springs, move to the capture position. The latch drive actuators pull the latch drive link down and clamp the two frames together and engage the alignment keys. The drive actuator springs and solenoids are dual to provide operation after one failure. The mechanism may also be driven manually by rotating the eccentric with a crank.

Figure 3-11 illustrates a dual motor rotary actuator which has been qualified by MDAC for the PAM program. Although this actuator is larger than is required for the latch actuator, it serves to demonstrate the dual motor drive concept to be used. Both DC motors normally drive through a differential planetary gear train to the output shaft If one motor fails either by loss of power or jams, the other motor will drive the output shaft at full torque at half the rate. A brake on the armature of each motor prevents backdriving the failed motor with the active motor. A declutching mechanism between the motor and the latch would be incorporated to allow manual operation by an EVA astronaut if both power sources failed.

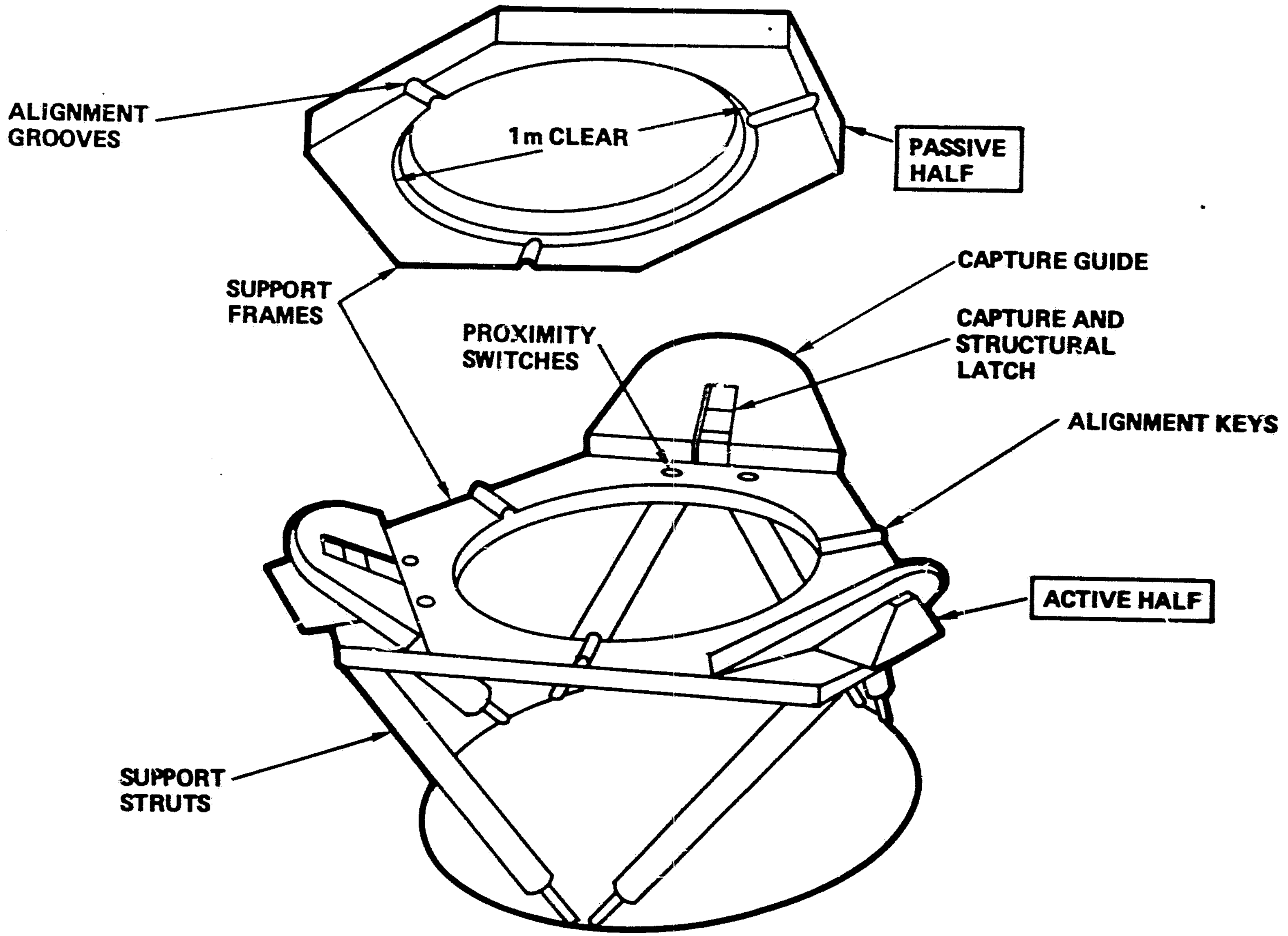


Figure 3-9. Hexagonal Frame — Berthing Latch Interface Mechanism (BLIM)

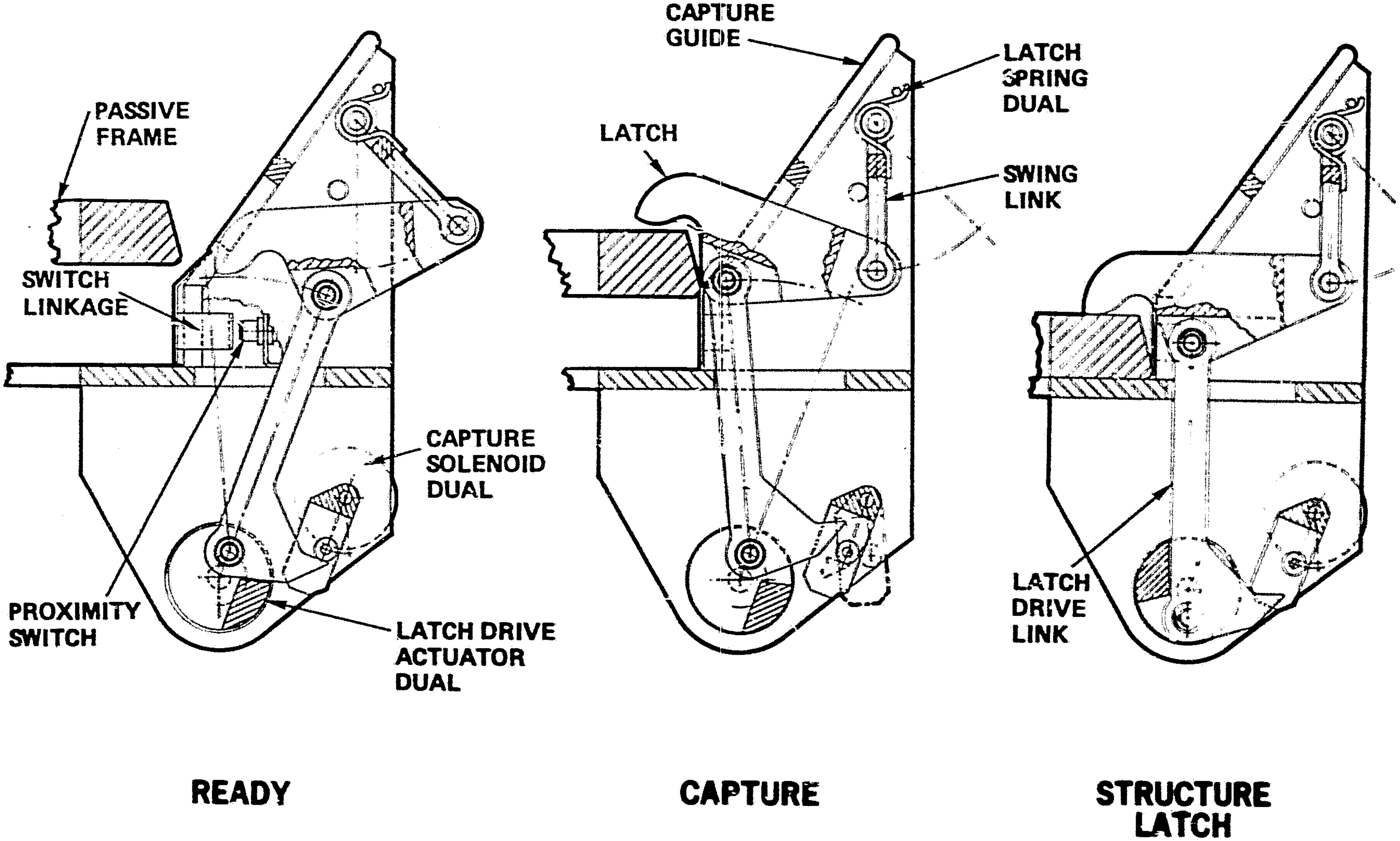


Figure 3-10. Capture and Latch Mechanism

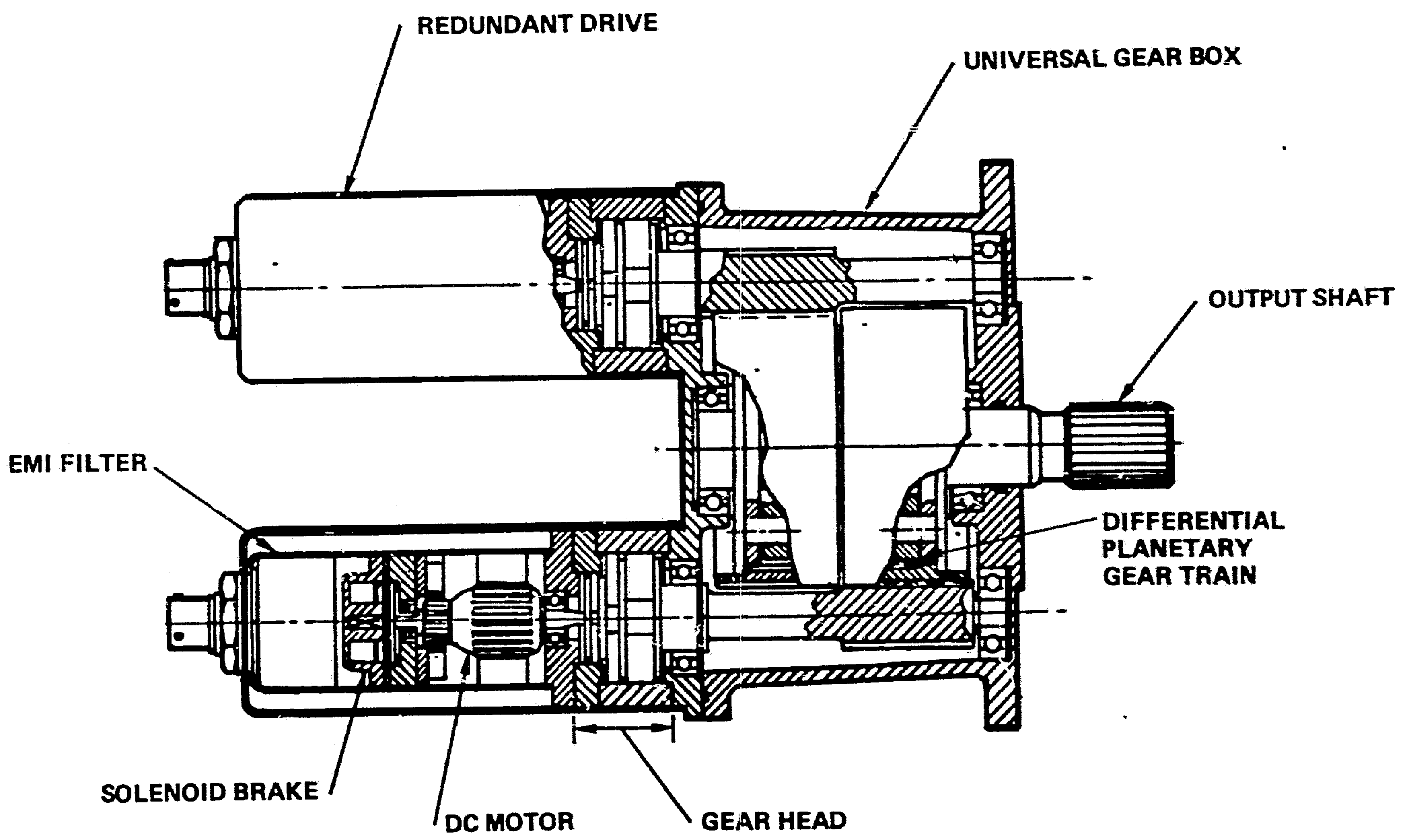


Figure 3-11. Dual Motor Rotary Actuator

3.4 BERTHING UMBILICAL INTERFACE DESIGN--TASK IV

The berthing umbilical interface requirements are based on the potential interface between the Orbiter and a space platform and/or a power module. This represents a maximum case for functional interfaces. The interface between pallet and platform would require fewer functional interfaces. Following is a listing of the requirements derived for the berthing umbilical interface:

1. Electrical power transfer – The umbilical system will transfer electrical power at the berthing interface. The electrical power wiring will consist of three circuits each with the capacity for 8 kW at 28 to 33 VDC.
2. Data transfer – The umbilical system will transfer data at the berthing interface. The data circuits will consist of the following:
   - Payload scientific data at rates to 5 MBPS
   - Control and display functions (20 circuits)
   - Caution and warning (two circuits)
   - Bidirectional data bus (1.024 MHZ)
   - Hardware command circuit (1 kBPS)
   - Telemetry (4 kBPS).
3. Coolant fluid transfer – The umbilical system will transfer coolant fluid at the berthing interface. Two coolant circuits (four lines) will be provided. Each line will be capable of flowing 2175 lb/hr of Freon 21 with a pressure drop of 5 psi maximum
4. Mechanical compatibilitv – The umbilical mechanism will be compatible with the physical mating of two active berthing latch mechanism halves.

As illustrated by Figure 3-12 the umbilical interface consists of two and potentially three mechanisms mounted behind the three clear sides of the hexagonal frame of the active half of the BLIM. The mating half of the umbilicals are fixed to the corresponding sides of the passive half of the BLIM. Two mechanisms are required to carry the electrical power, data and coolant fluid lines. The third mechanism position is available for growth.

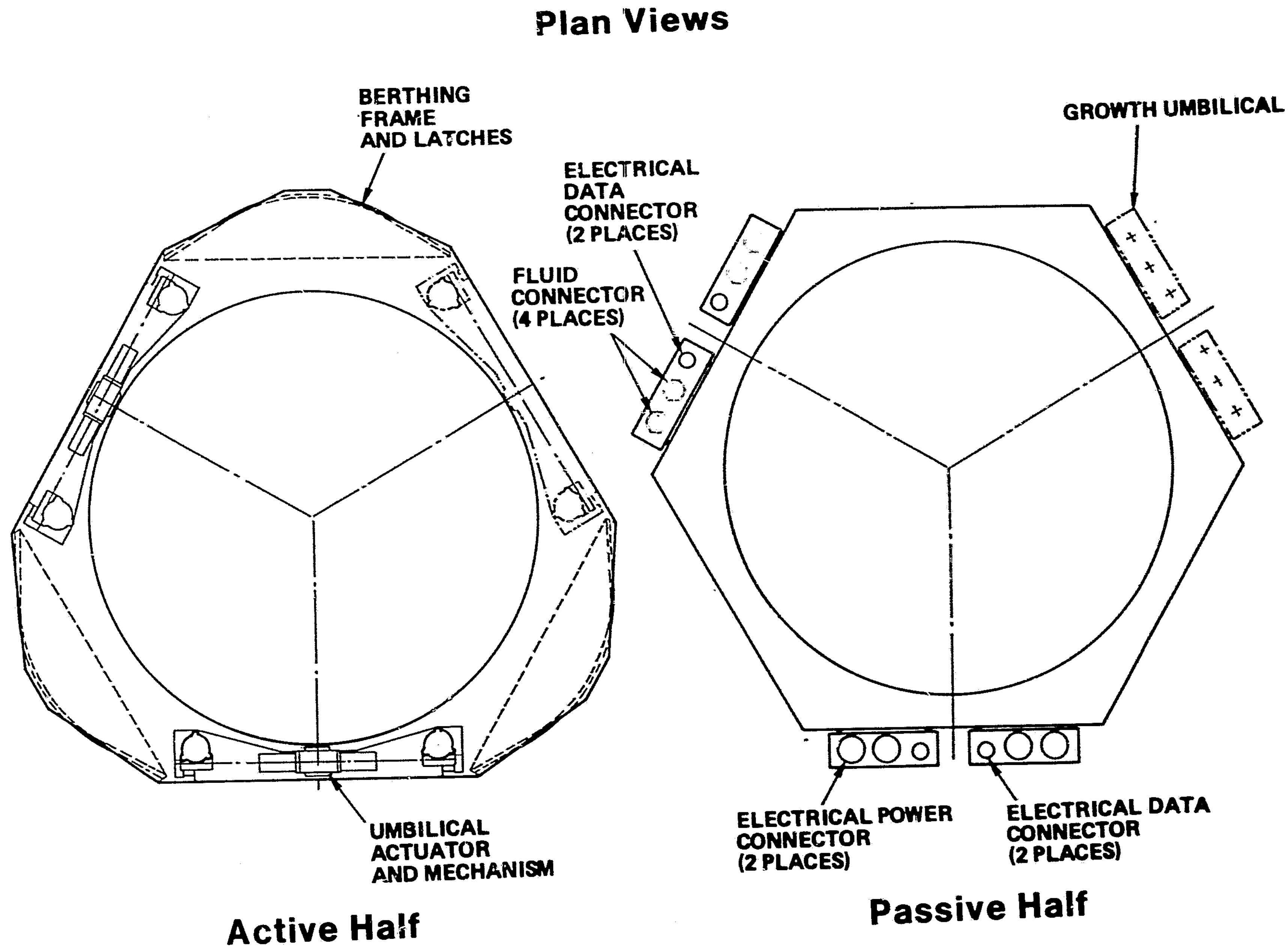


Figure 3-12. Berthing Umbilical Interface

The engagement sequence of the active side of the umbilical is illustrated by Figure 3-13. The umbilical mechanism on the active half is stowed behind the face of the berthing frame and the mating connectors are fixed on the outside of the passive frame. The umbilical carrier is mounted on linkage which is rotated by cam followers. As the links' pivot points are moved down by the jackscrew the umbilical carrier is moved outboard and down engaging the fixed side of the umbilical. Figure 3-14 shows the carrier retracted and two active halves of the BLIM mated. A clearance slot in the center of the carrier is provided to allow engagement of the structural latch.

Dual motors are used to drive the two worm gears and jackscrews. A clutch is provided in the drive shaft to allow operation by an EVA astronaut if both motors fail to operate.

3.5 ADAPTIVE END EFFECTOR (AEE) REQUIREMENTS AND DESIGN — TASKS V AND VI

Tasks V and VI are combined in this report because Task VI is actually a continuation of Task V. They were separated in the study plan because of contractual considerations.

The requirements for the end effector were derived based on RMS configuration and performance, the handling of objects to be used in platform construction and the anticipation that operator feedback will aid in handling fragile objects.

Following is a listing of the requirements for the AEE. The key requirements are noted with an asterisk and indicate significant issues in the design of the system.

1. Object — Provide an end effector for the RMS with the capability to grasp, hold, and maneuver objects which are not equipped with a grapple fixture and have no preplanned interface for mating with the RMS.
2. RMS interface — The adaptive end effector (AEE) will mate with the special purpose end effector (SPEE) of the RMS.

* 3. Grasp — The grasp of the AEE will have the capability of holding cylindrical, spherical, flat, and irregular shaped objects up to a dimension of 6 in. The fully open span of the grasping mechanism will be 7 in. minimum.

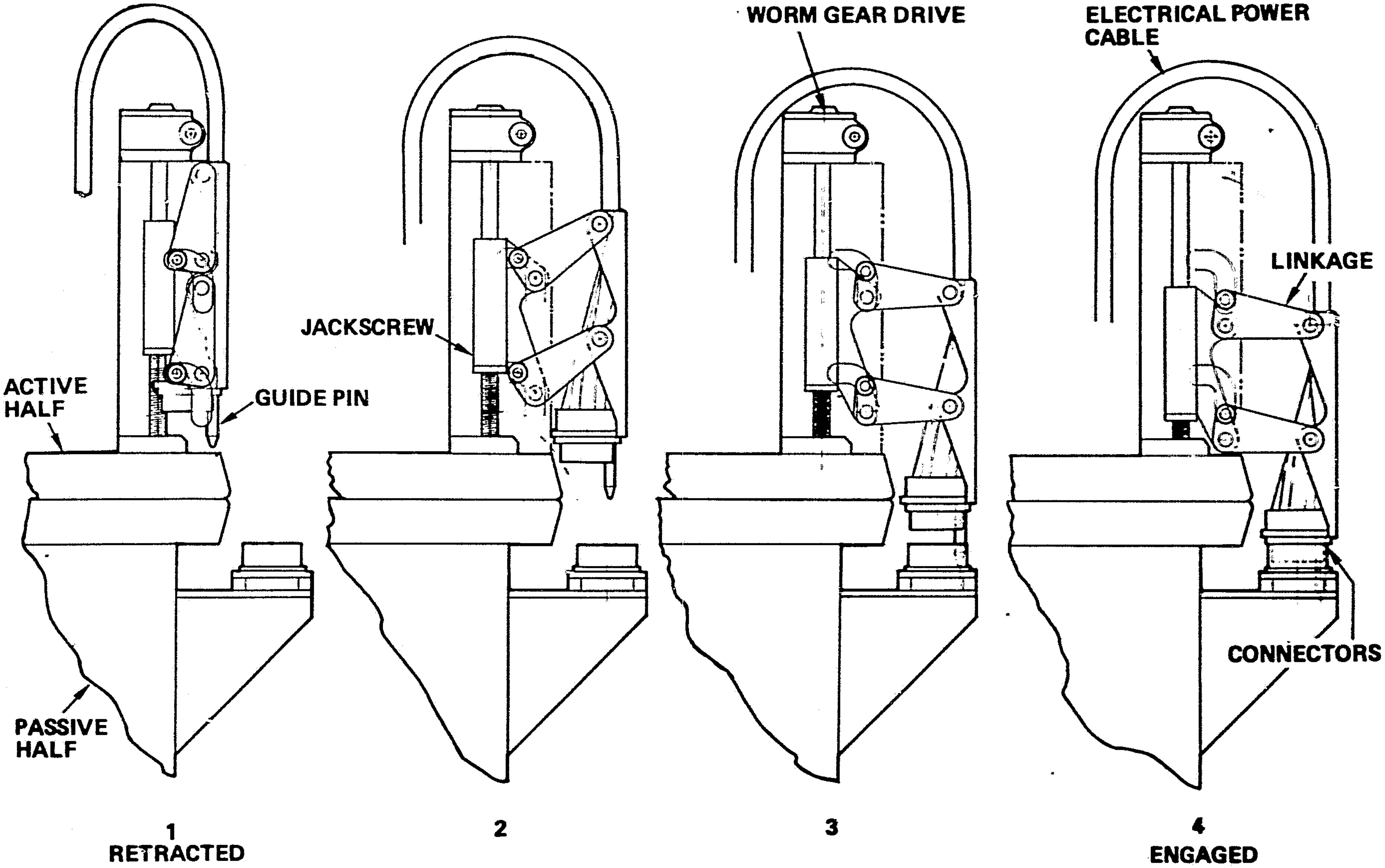


Figure 3-13. Berthing Umbilical Interface Engagement Sequence

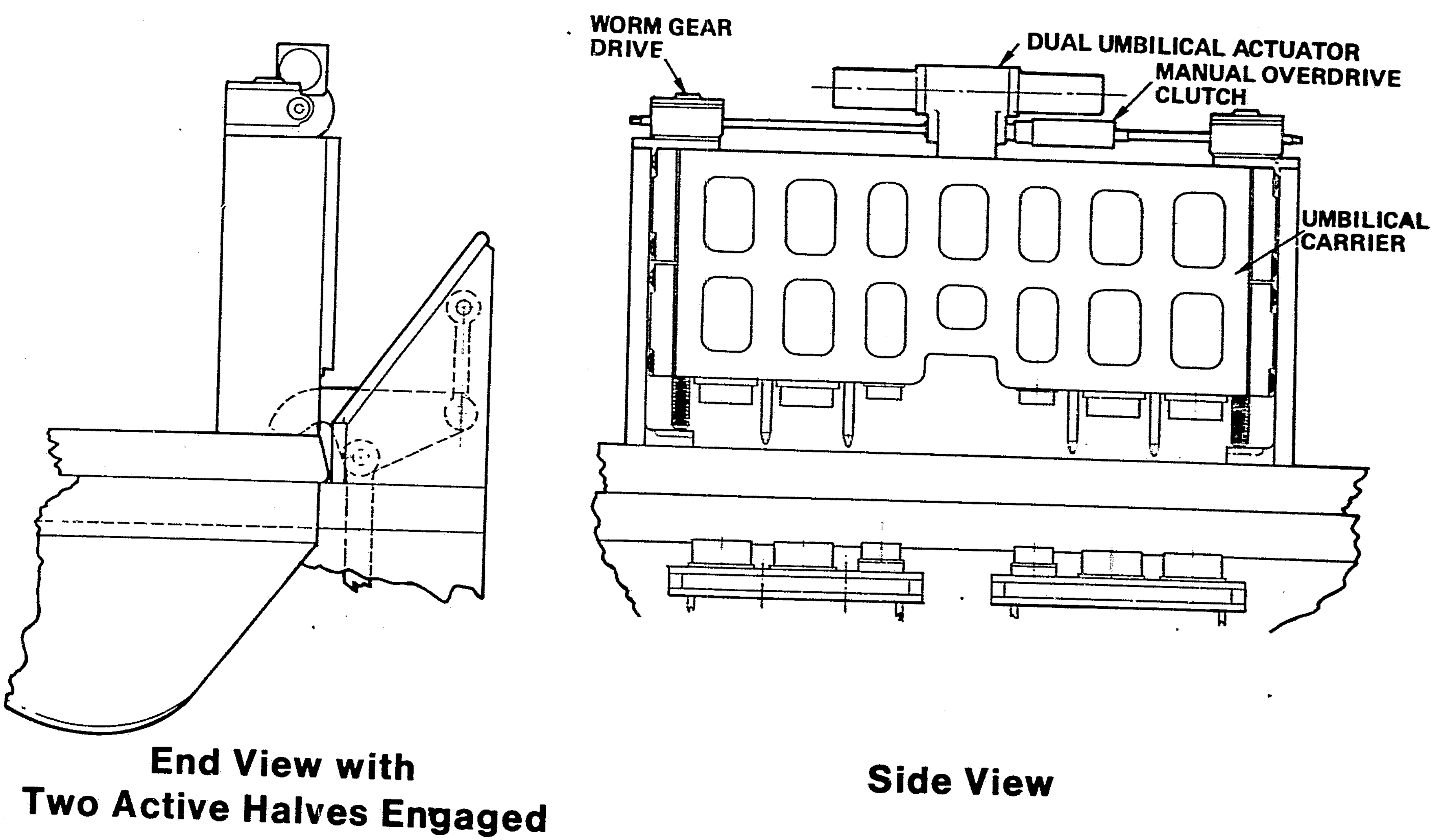


Figure 3-14. Berthing Umbilical Interface

* 4. Visibility — The gripping mechanism of the AEE will be within the field of view of the wrist CCTV camera and light mounted on the RMS.

5. Kinematics — Grasping mechanism jaws will remain parallel during operation and not translate in the plane of the jaws during grasping or release operation.

6. Jaw compliance — The jaws of the grasping mechanism are to have a compliant surface. The coefficient of friction between the surface of the jaws and anodized aluminum will be as high as possible but not less than 0.8.

7. Power — The AEE will be powered by 28 to 33 VDC electrical power. The system will not draw more than 150 watts.

8. Stowage — The AEE will be stowed in a container or rack within the Orbiter cargo bay and within the reach envelope of the RMS. The grapple fixture of the AEE will be exposed to allow capture by the RMS SPEE. The AEE will be secured to the stowage provisions to prevent disengagement during the launch and descent environments imposed by the Orbiter. The securing mechanism will be operated by the drive system of the AEE jaws.

* 9. Control — The grasping mechanism of the AEE will be operated by a hand controller integrated with or in close proximity to the RMS controls. Displacement of the controller will cause a proportional displacement of the grasping mechanism of the AEE. The grasping force encountered by the mechanism will cause a proportional resisting force at the hand controller. A hand controller lock will be provided to allow the grip at the AEE to be maintained with hands-off the controller.

* 10. Grasping Force — The jaws of the AEE will have sufficient grasping force to impart a torque of 200 ft lb to a 3-in.-diameter cylinder with a coefficient of friction between the jaws and cylinder of 0.8.

11. Grasping rate — The no load rate of the grasping mechanism will provide for full open to close or close to full open time of 7 sec maximum.

Figure 3-15 illustrates the arrangement of the RMS end-effector, viewing light (VL), and TV camera (TVC). The AEE will mate with the standard end effector. The jaws will be offset from the RMS centerline to provide visibility for the TV camera.

The schematic showing the basic operating principle for the AEE is illustrated by Figure 3-16. The AEE system consists of an electrically driven jaw moving with respect to a fixed jaw. The jaws have elastic surface pads and the fixed jaw contains force sensors. A jaw position potentiometer tracks the moving jaw position. The controller consists of a lever attached to a position command potentiometer and a spring. A force applied at the control lever produces an output from the command potentiometer which is proportional to the applied force. The command causes the motor to run to move the jaw until the output of the force sensors in the jaw balances the command signal. The gripping force of the jaw is proportional to the force applied to the hand controller.

The illustration in Figure 3-17 is a concept sketch showing the AEE stowed in a fixture or "holster" at the side of the Orbiter cargo bay. The fixture could be attached to a bridge fitting rail or directly to Orbiter structure. The AEE with attached grapple fixture would be installed in the holster prior to launch. The latches to hold the AEE in the fixture are operated by jaw motion. The target for RMS engagement is attached to the holster and therefore would not obstruct the field of view when working with the AEE.

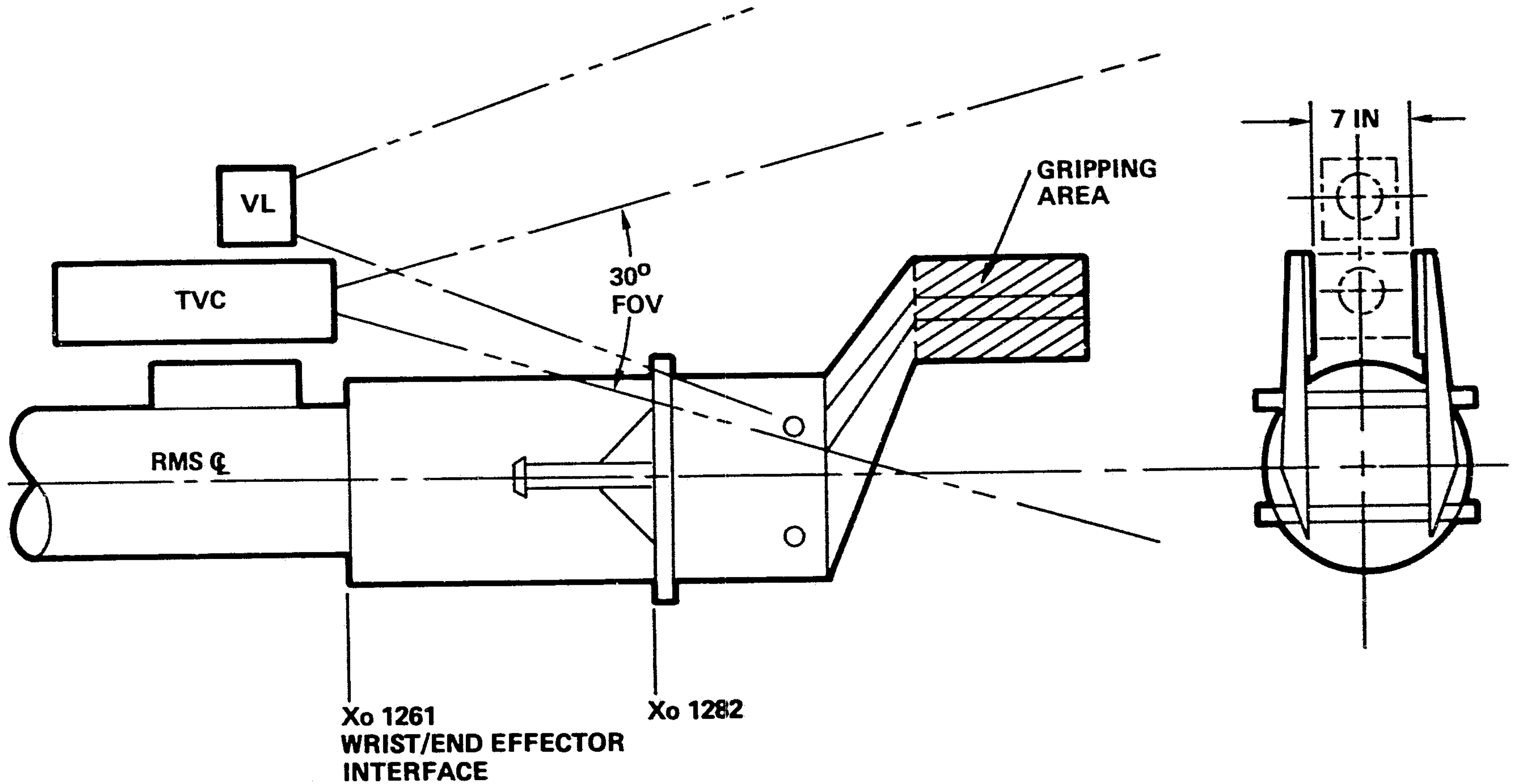


Figure 3-15. Adaptive End Effector (AEE) Geometry

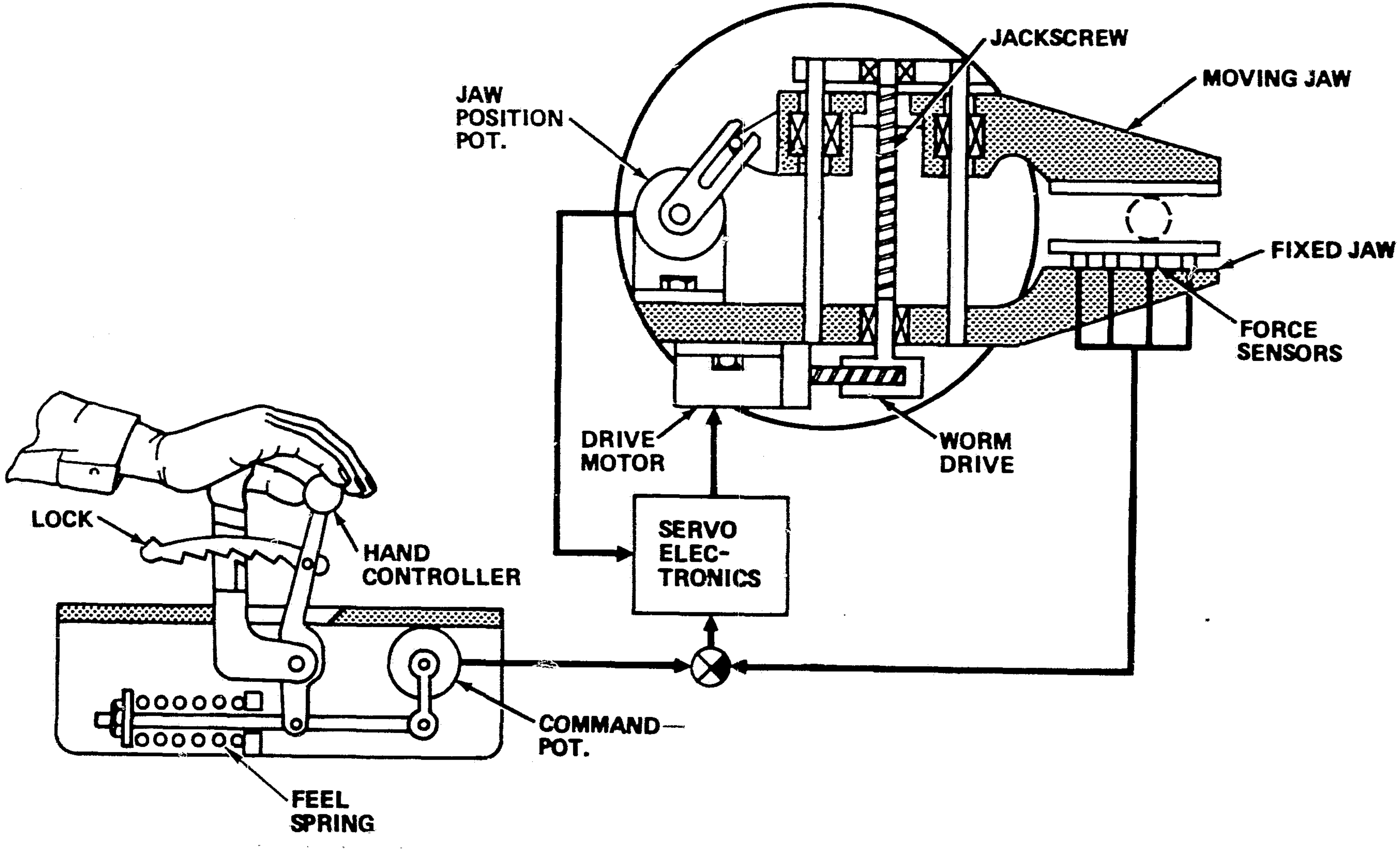


Figure 3-16. Adaptive End Effector Schematic

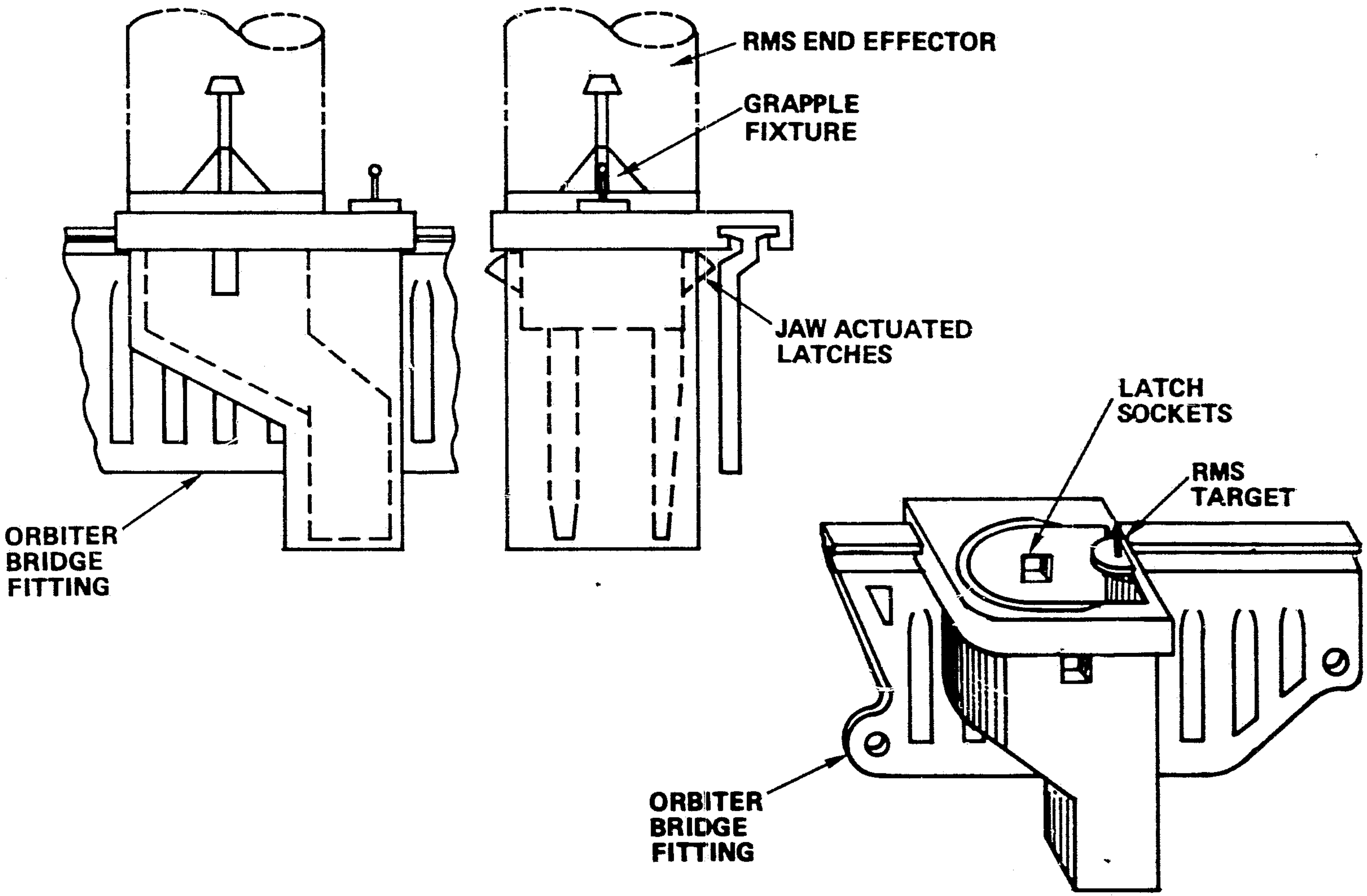


Figure 3-17. AEE Stowage Holster Concept

Section 4
MODEL DESCRIPTION AND DEVELOPMENT

4.1 BERTHING LATCH INTERFACE MECHANISM (BLIM)

The BLIM model design was prepared and a complete set of assembly and detail drawings produced which were previously delivered to JSC. The model was fabricated full scale from aluminum with all functional elements operable. Figure 4-1 illustrates the active half of the mechanism during assembly. Commercial-type components were used in order to minimize procurement lead times and costs. Rotary solenoids are used to release the capture mechanism and DC gearhead motors are used to operate the structural latches. Cam-driven limit switches are installed on each latch to interrupt the circuit to the motor at each travel limit.

During checkout the gearhead motors initially installed failed because of insufficient strength in the output stage of the gear train. Subsequently a different and stronger gearhead motors were located and adapted to the design. Figures 4-2 and 4-3 show the active and passive halves of the SLIM model mated and a closeup of the capture and lock mechanism.

Control of the BLIM model is designed to be manual with indicator lights providing feed-back on various functions. Figure 4-4 illustrates the arrangements of the BLIM control console. To operate the system a 28 VDC power source capable of 30-ampere current is required. If the active and passive halves of the mechanism are separated and they are to be mated the Capture Enable Switch is "ON," the motor control switch is in the "Latch Drive" position and the Latch/Release Enable Power switch is in the "ON" position. The motor indicator lights will show all these "Latch Drive" lights burning and the Release Drive Lights out. As the two halves of the BLIM are mated and the capture position is reached, the three capture Proximity Sensor Lights will come on. When all three lights are on actuation of the push-type "Capture" switch causes the capture latches to be released locking the two

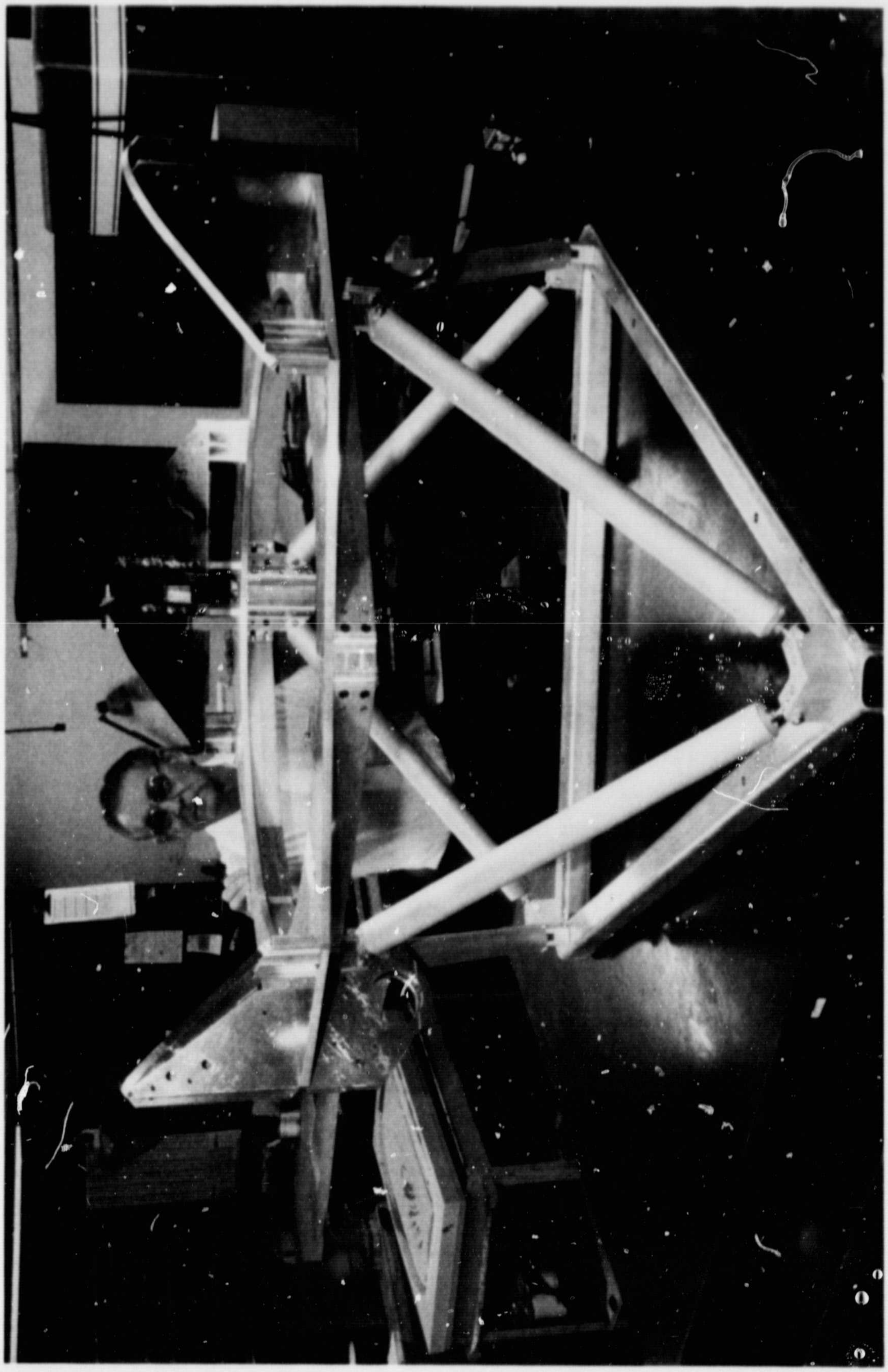


Figure 4-1. BLIM Active Half During Fabrication

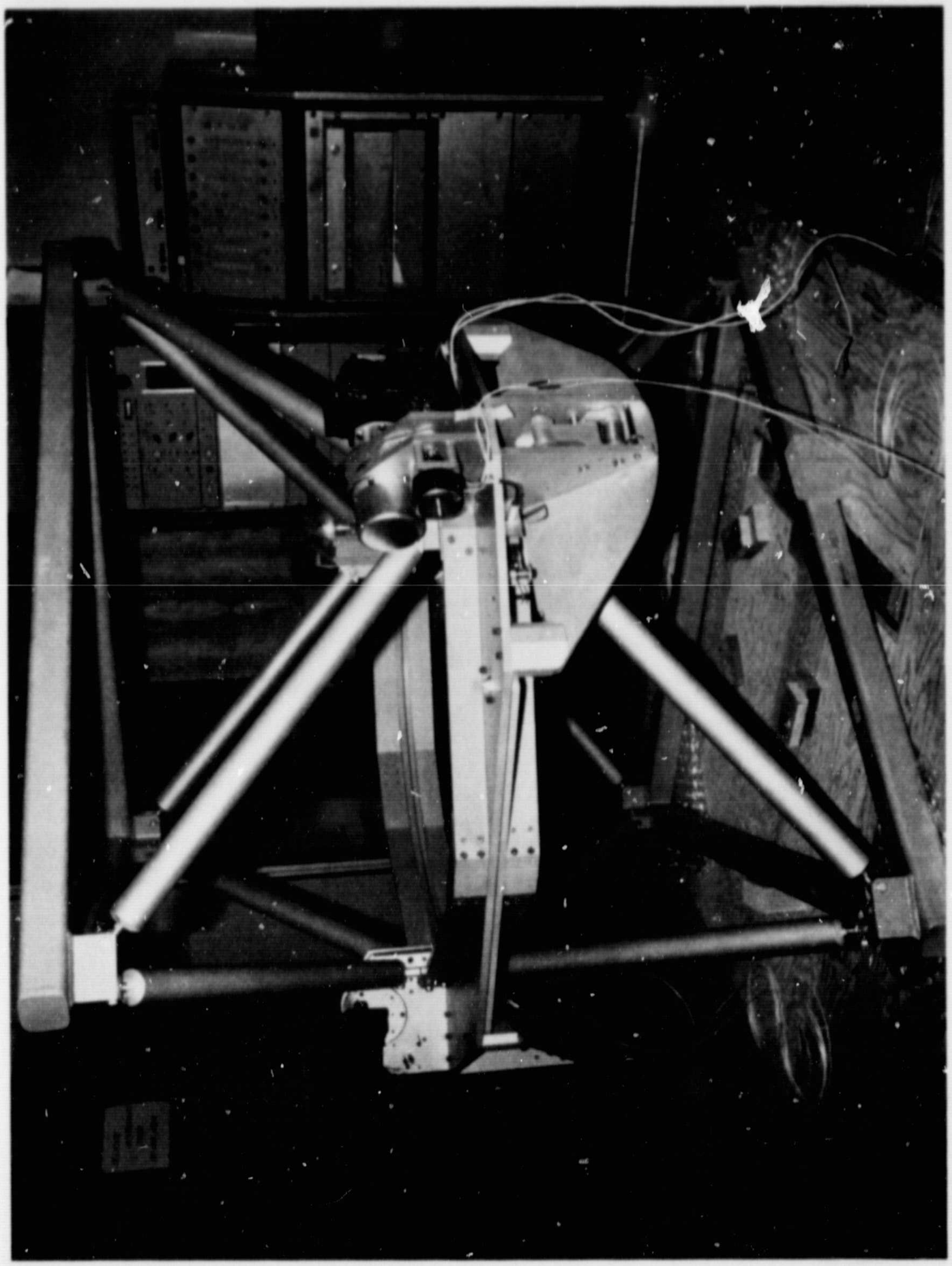


Figure 4-2. BLIM Active and Passive Halves Mated

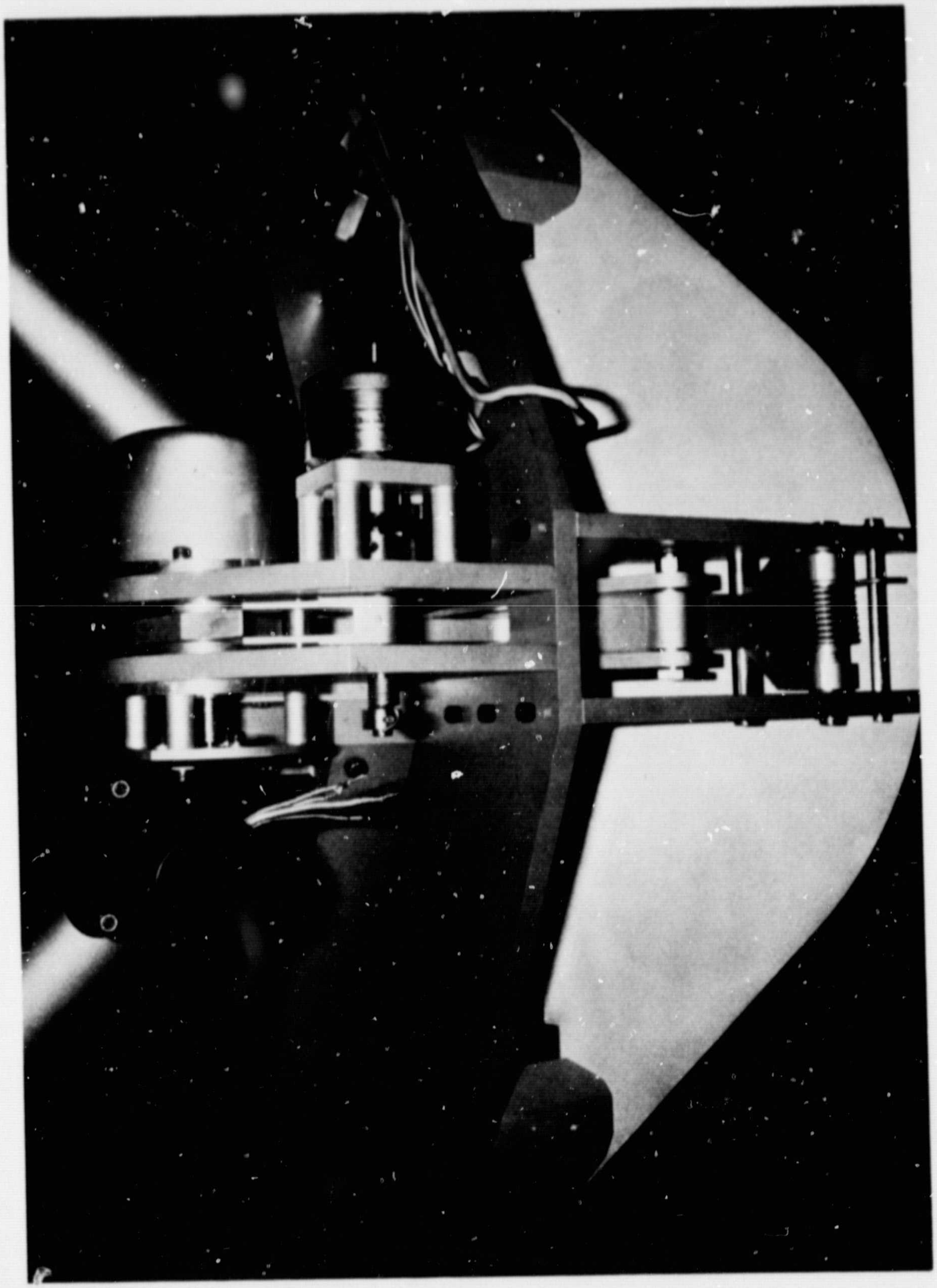


Figure 4-3. BLIM Capture and Lock Mechanism

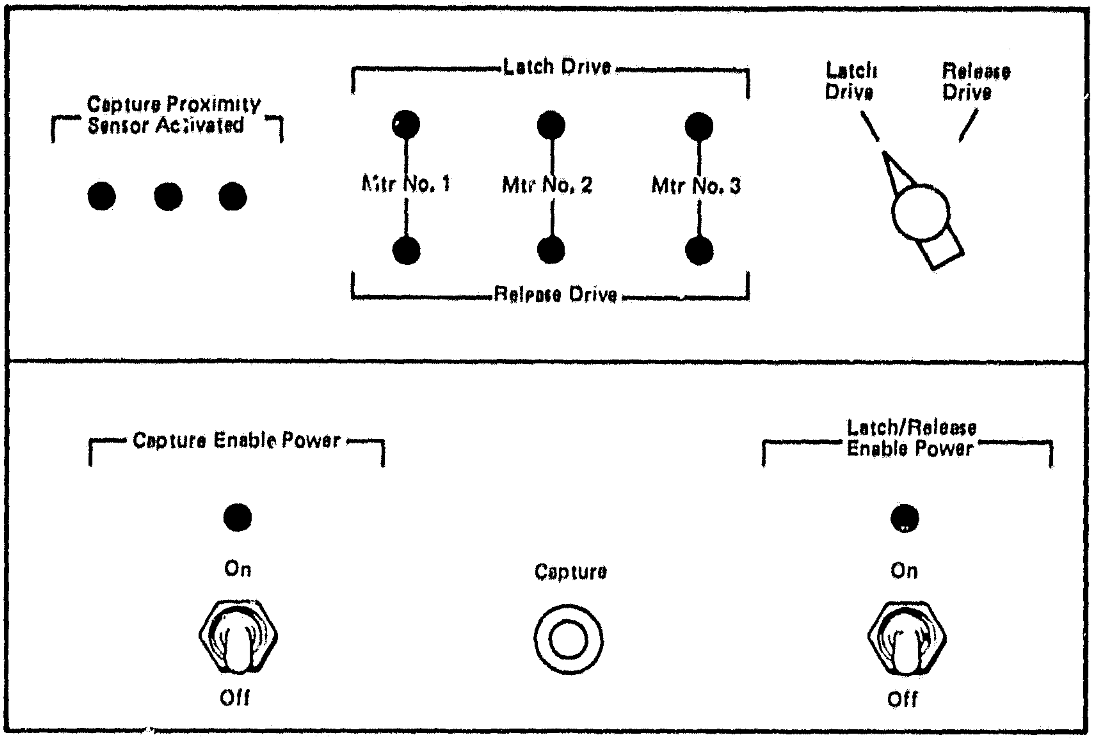


Figure 4-4. BLIM Control Console

halves of the BLIM loosely together. By rotating the Latch Drive switch to the "Latch Drive" position the motors will drive the latches to the over-center position causing the two halves of the BLIM to be structurally tied together. At this time the Latch Drive lights will all be out and the Release Drive lights burning. To release the mechanism rotate the Latch Drive switch to the release drive position and the motors will drive the latches to the release and reset position. Figure 4-5 is the electrical schematic for the BLIM electrical control system.

4.2 ADAPTIVE END EFFECTOR (AEE)

The AEE Model, like the BLIM, was fabricated from a complete set of detail and assembly drawings which were previously delivered to JSC. It was built full scale and the initial intent was to provide performance equal to the flight unit i.e. 1000-lb gripping force. The unit is designed structurally for the full load; however, motor availability prevented procurement of a motor which can produce full capability. Figure 4-6 illustrates the AEE and its control module. The system requires 24 volts and ±10 volts DC power for operation. With power applied to the control, the moving jaw will run to

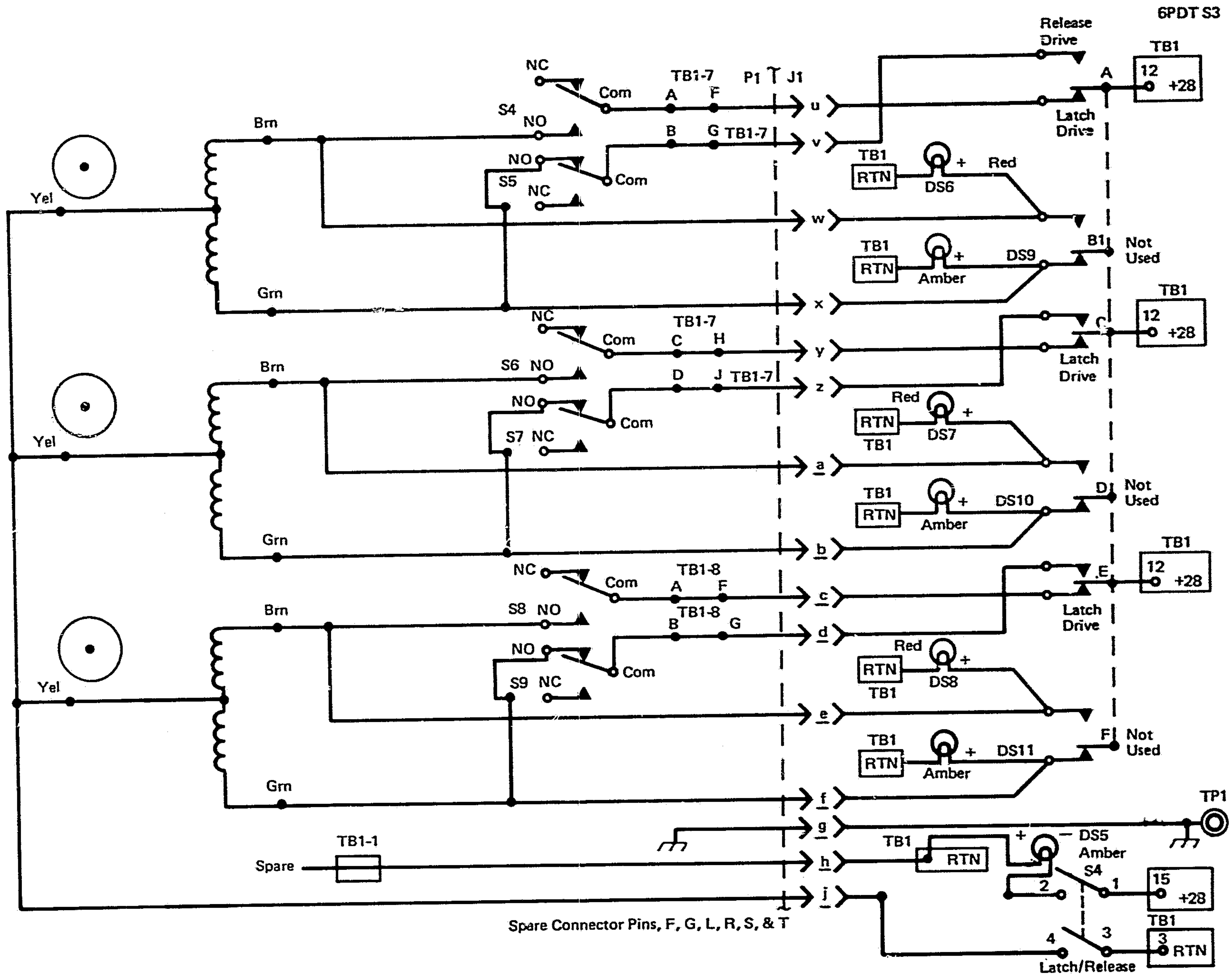


Figure 4-5A. Berthing Latch Interface Mechanism Electrical Schematic

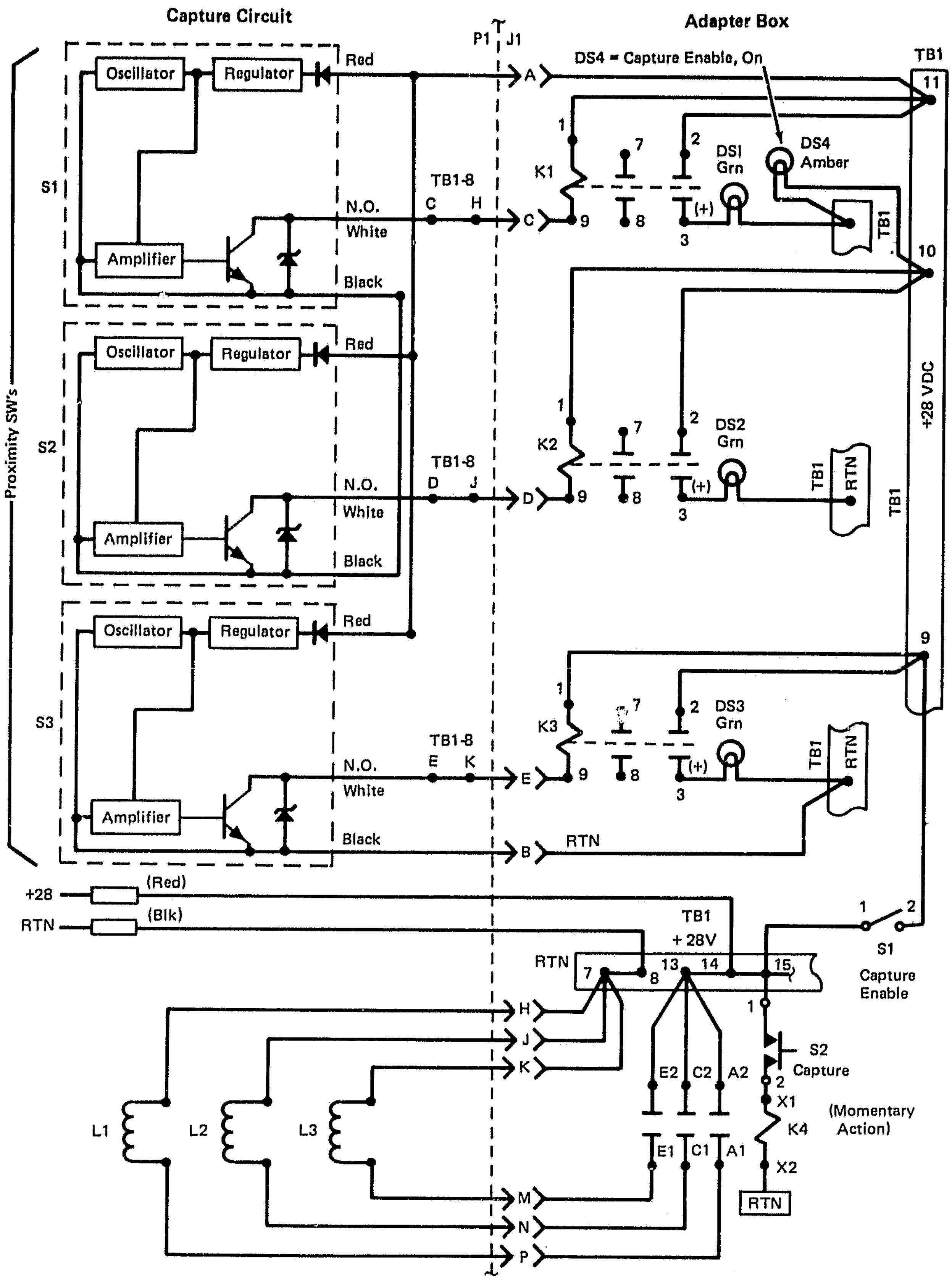


Figure 4-5B. Berthing Latch Interface Mechanism Electrical Schematic

Junction Module Wiring Diagram Berthing Latch Interface Unit

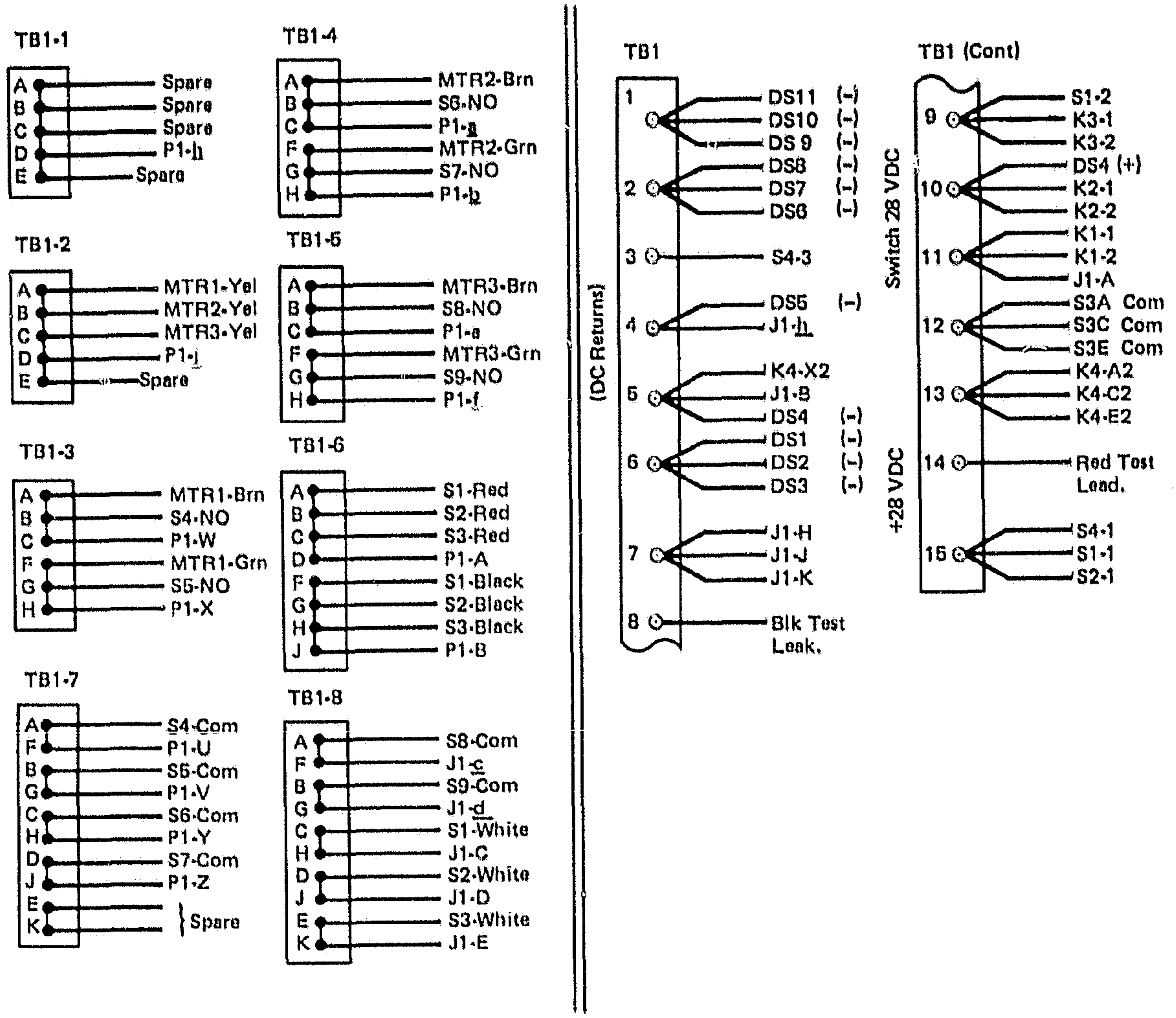


Figure 4-5C. Berthing Latch Interface Mechanism Electrical Schematic

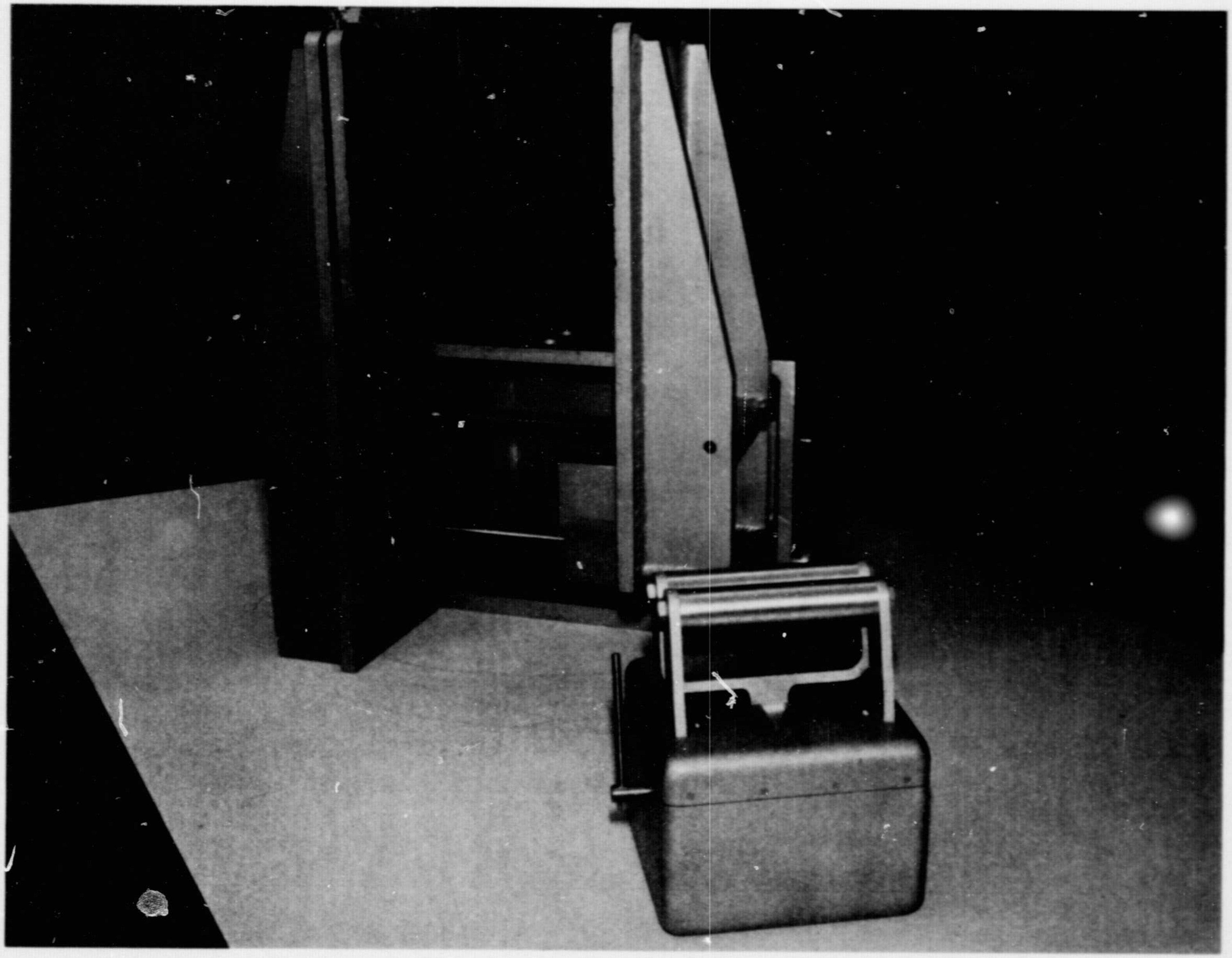


Figure 4-6. Models of Adaptive End Effector and Control Module

the full open position. A limit switch at this position will remove power to the drive motor. When the hand grips are squeezed on the control module the moving jaw will run at full rate, approximately 1 in./sec, toward the closed positions. If an object is between the jaws they will grip the object with a force proportioned to the force exerted on the controller. Release of the hand grip will cause the jaw to return to the open position. Figure 4-7 illustrates the electrical schematic of the AEE control system. Figure 4-8 illustrates the circuit board layout.

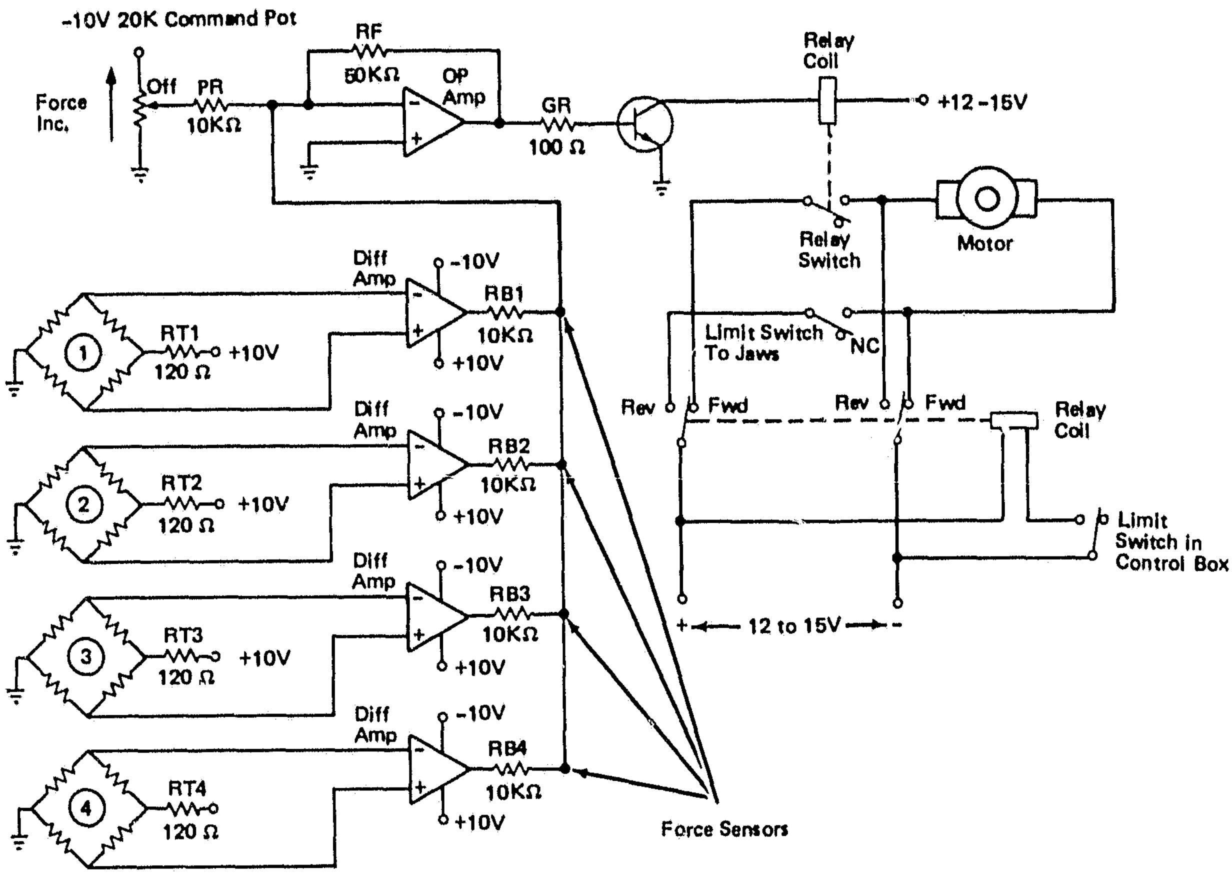


Figure 4-7A. Adaptive End Effector Electrical Schematic

It was found that because of the limited torque of the motor and the relay switching, the force sensitivity of the jaws was less than desirable for a flight article. Future modifications to the model to incorporate a higher torque motor and proportional servo electronics could improve the force resolution of the jaws. The design of the model did not attempt to minimize weight, therefore the unit is quite heavy. Approximately 50% weight reduc-

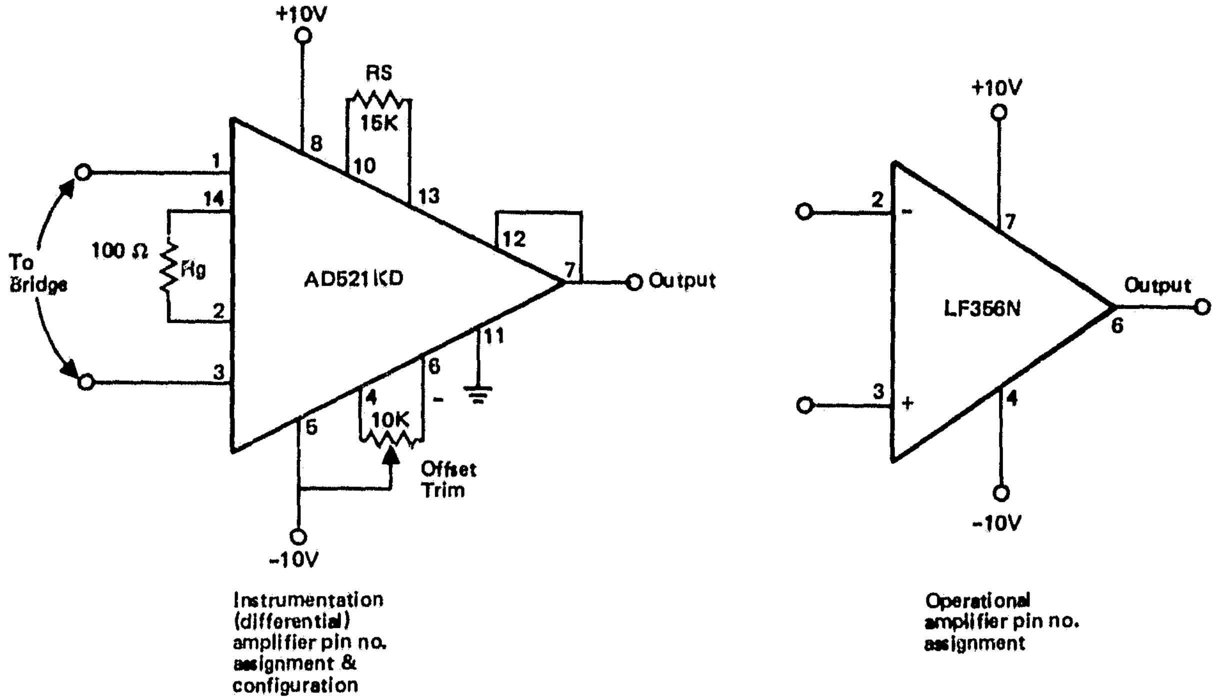


Figure 4-7B. Adpative End Effector Electrical Schematic

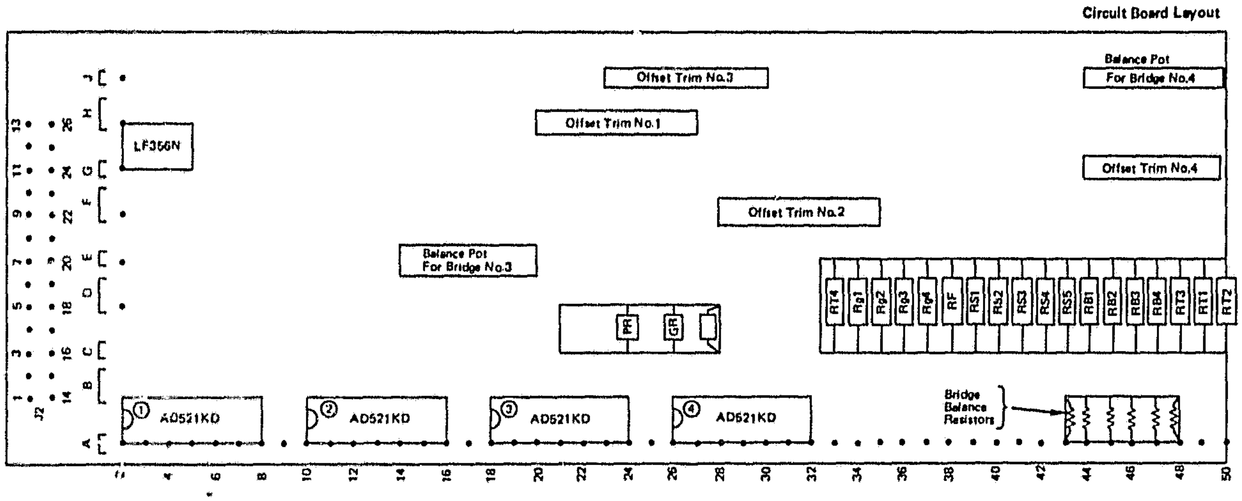


Figure 4-8. Adaptive End Effector Circuit Board Layout

tion in the model could be accomplished through the use of lighting holes and elimination of excess material. The flight weight design would make use of forgings, castings, etc. to greatly reduce weight of the unit.

Appendix
STUDY PLAN

MCDONNELL DOUGLAS

SPACE PLATFORM ADVANCED TECHNOLOGY

Study Plan

MARCH 1980

DRL T-1579
DRD MA-793T

APPROVED BY: Gen C Burns
G. C. BURNS
STUDY MANAGER
MDAC

APPROVED BY: L M Jenkins
L. M. JENKINS
STUDY MANAGER
NASA/JSC

PRECEDING PAGE BLANK NOT FILMED

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY-WEST
5301 Bolsa Avenue, Huntington Beach, CA 92647

PREFACE

This study plan presents the tasks to be performed in the Space Platform Advanced Technology Study and the schedule for study completion. Major milestones and reviews also are identified. This study plan constitutes the study task product for Task 5.7 of the Statement of Work.

This plan is submitted to the National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, Houston, Texas in compliance with DRL No. T-1579; DRD No. MA-793T.

Section 1

INTRODUCTION

The purpose of the Space Platform Advanced Technology Study is to develop a deeper understanding of the technology aspects of a space platform concept developed earlier under Contract NAS9-15532 and documented in MDAC report MDC G7832. This document contains a plan for conduct of further design definition in specific areas, particularly the mechanical aspects of the reference configurations previously developed for the Johnson Space Center (JSC) and Langley Research Center (LaRC) of NASA.

The study will consist of five discrete tasks, performed in a 14-month time period beginning November 1979. Conceptual reference designs developed in the previous contract will constitute the design starting point for this study. The contents of each task are described in the subsequent text, followed by information on study Scheduling, Documentation and Organization.

The five tasks described herein represent the work to be accomplished for a total contract funding of $125,000.

Figure 1 illustrates the overall flow of tasks along with inputs to and outputs from the study.

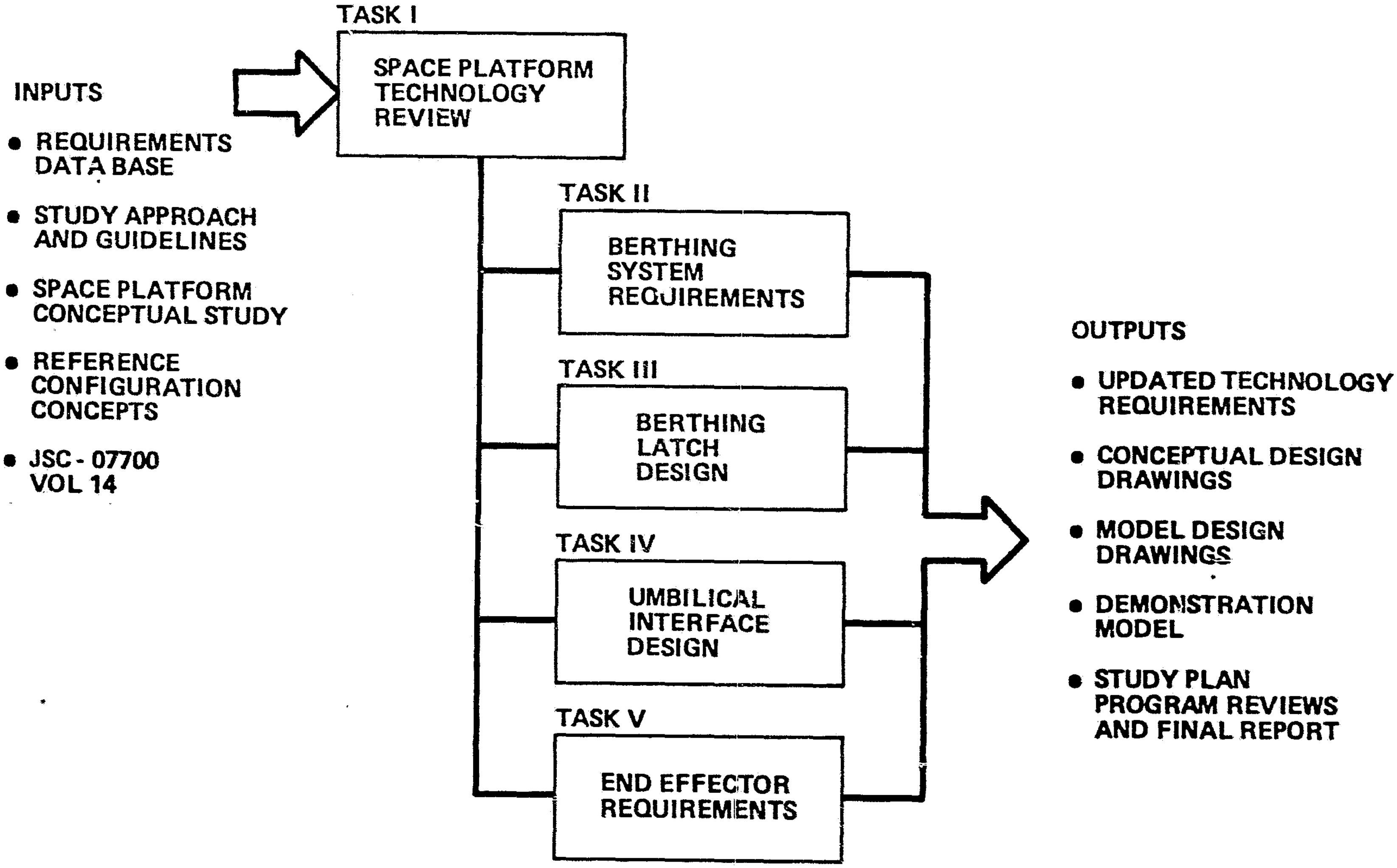


Figure 1. Study Task Flow

Section 2

TASK DESCRIPTIONS

Study Approach and Rationale

Mechanism requirements will be formulated based on platform concepts developed under Contract NAS9-15532 and documented in MDAC report MDC G7832 and current space platform studies. Different space platform configurations are evolving as study programs progress, however, all configurations have common requirements for mechanical mechanisms to berth platform segments and payloads and to handle and maintain these elements while attached to the Orbiter. A number of these common mechanisms will be selected to be explored through preliminary design. The goal will be to establish standards which may be adopted and used in conjunction with all platform configurations. Demonstration models of selected mechanisms will be fabricated to provide confidence in operational performance.

Task I

SPACE PLATFORM TECHNOLOGY REVIEW

Objectives

The objectives of this task are:

- Establish the technology items to be investigated by this study.
- Prepare a study plan to define the detail tasks to be accomplished.
- Establish schedules program milestones and budget allocations.

Approach

A review of technology drivers identified in platform conceptual systems study will be made. Candidate technology items for further investigation will be identified. Selection of these items for study will be based on universal adaptability to all platform concepts. A study plan will be prepared reflecting these technology choices and the depth to which the investigation will go. Program milestones, schedules and budgets will be prepared and submitted to JSC for concurrence.

Task Output

- Study Plan
- Schedules
- Budget

Task II

BERTHING SYSTEM REQUIREMENTS FOR PLATFORM SERVICING AND PAYLOAD CHANGEOUT

Objectives

The objective of this task is:

- Establish berthing system requirements.

Approach

The requirements for the berthing system will be derived by analyzing the positioning requirements of the various configuration platforms for deployment servicing and payload changeout. Consideration will be given to Orbiter cargo bay volume available for stowage of the berthing fixture and compatibility with other Orbiter payloads such as Spacelab.

Rationale

The conceptual systems studies of Space Platforms which have been done have identified the need for a berthing fixture to be used in conjunction with the Orbiter and the RMS to deploy and service the platforms. Although the berthing arrangement has taken different forms depending on the platform configuration, all platform concepts require the berthing function. Several alternatives exist such as, use of standard Orbiter retention latches, berthing fixture to be part of Orbiter or part of platform, etc.

Task Output

- Berthing system requirements list

Task III

BERTHING LATCH MECHANISM DESIGN FOR PLATFORM SEGMENTS, PAYLOAD PALLETS AND ORBITER ATTACHMENT

Objectives

The objectives of this task are:

- Establish berthing latch requirements.
- Select baseline latch/interface for berthing.
- Prepare preliminary design layout.
- Establish design details and weight.
- Fabricate demonstration model.

Approach

The requirements for the berthing latch mechanism will be derived based on the use of the Orbiter RMS to position and hold the payload in berthing position.

Various docking and berthing latch mechanisms will be examined and a baseline selection made based on function weight cost, etc. A preliminary design layout of the baseline design will be prepared and details of the latch mechanisms, drive linkage and actuation device, materials strength and weight will be established.

A full scale model of the two halves of the berthing interface will be designed and fabricated. The model will be suitable for demonstrating operating principal and can be used in combination with the RMS simulator on the air bearing floor.

Rationale

The attaching of platform segments, payloads to platform and platform to Orbiter is a common requirement for all platform configurations. The design

of a standardized design berthing interface may be used with all platform configurations.

Task Output

- Berthing latch mechanism requirements list
- Preliminary design of berthing mechanism
- Model design of berthing mechanism
- Full scale demonstration model

Task IV

BERTHING UMBILICAL INTERFACE DESIGN FOR SPACE PLATFORMS

Objectives

The objectives of this task are:

- Establish umbilical requirements
- Examine alternate arrangement and actuation concepts
- Select a baseline umbilical arrangement
- Prepare a preliminary design layout

Approach

The requirements for the Berthing Umbilical Interfaces will be derived based on pallet design, payload needs and various platform configuration considerations as defined by prior and ongoing platform studies. Alternate arrangements will be conceived based on the requirements and then evaluated. The evaluation will be based on compatibility with the berthing latch mechanism derived in Task III as well as complexity, weight and operational flexibility. Accommodations will be made for electrical power and data transfer through one umbilical and coolant fluid through a second umbilical. A preliminary design layout of the umbilicals and actuating mechanisms will be prepared.

Rationale

The umbilicals between platform sections or between platform and payload pallet supplies a critical function and the reliability of this interface must be high. The umbilicals must work in conjunction with the latching mechanism to be developed in Task III.

Task Output

- Umbilical requirements list
- Preliminary design of umbilical mechanism

Task V

END EFFECTOR REQUIREMENTS

Objectives

The objective of this task is:

- Establish end effector requirements

Approach

The requirements for an end effector will be derived based on projected usage in conjunction with future space platforms for assembly, deployment, maintenance and payload changeout.

Rationale

A special end effector to be used in conjunction with the RMS will be a necessary tool in erecting and maintaining a space platform. This task explores the requirements for grasping and handling irregular shaped objectives.

Task Output

- End effector requirements list

Section 3

STUDY PLAN

The study tasks, definitions, inputs and outputs have been documented in this study plan and prepared for submittal. Upon approval by NASA/JSC early in the study schedule, this study plan will guide the subsequent study activities then completion of the study. In order to assure a timely start on tasks which have an early output, a preliminary task outline will be submitted and NASA/JSC direction and approval obtained via telecon discussions. Tasks with later start dates will follow the standard review and approval procedure.

Section 4

SCHEDULE, DOCUMENTATION AND STAFFING

The schedule for this study (see Figure 2) is structured to provide timely conceptual design drawings of the selected technology items.

Documentation will be delivered in accordance with Attachment 1 to the Statement of Work. A study plan (DRD-MA-793T) will be delivered and letter-type monthly progress reports (DRD-MA-793T) will be made as shown in Figure 2. Briefing manuals will be prepared for the interim and final study reporting (DRD-MA-665TA) with facing page text.

The manload distribution of 2000*contract hours are distributed as follows:

Task I	Space Platform Technology Review and Program Management	600 hours
Task II	Berthing System Requirements	120 hours
Task III	Berthing Latch Interface Design	780 hours
Task IV	Umbilical Interface Design	380 hours
Task V	End Effector Requirements	120 hours

Past and current company contract and independent study effort for the Power Extension Package (PEP), 25 kW Power System, Science and Applications Platform and Advanced Platform Structures Requirements will also augment this study effort.

*Based on a total contract of $125,000 of which approximately $25,000 is allocated for model fabrication.

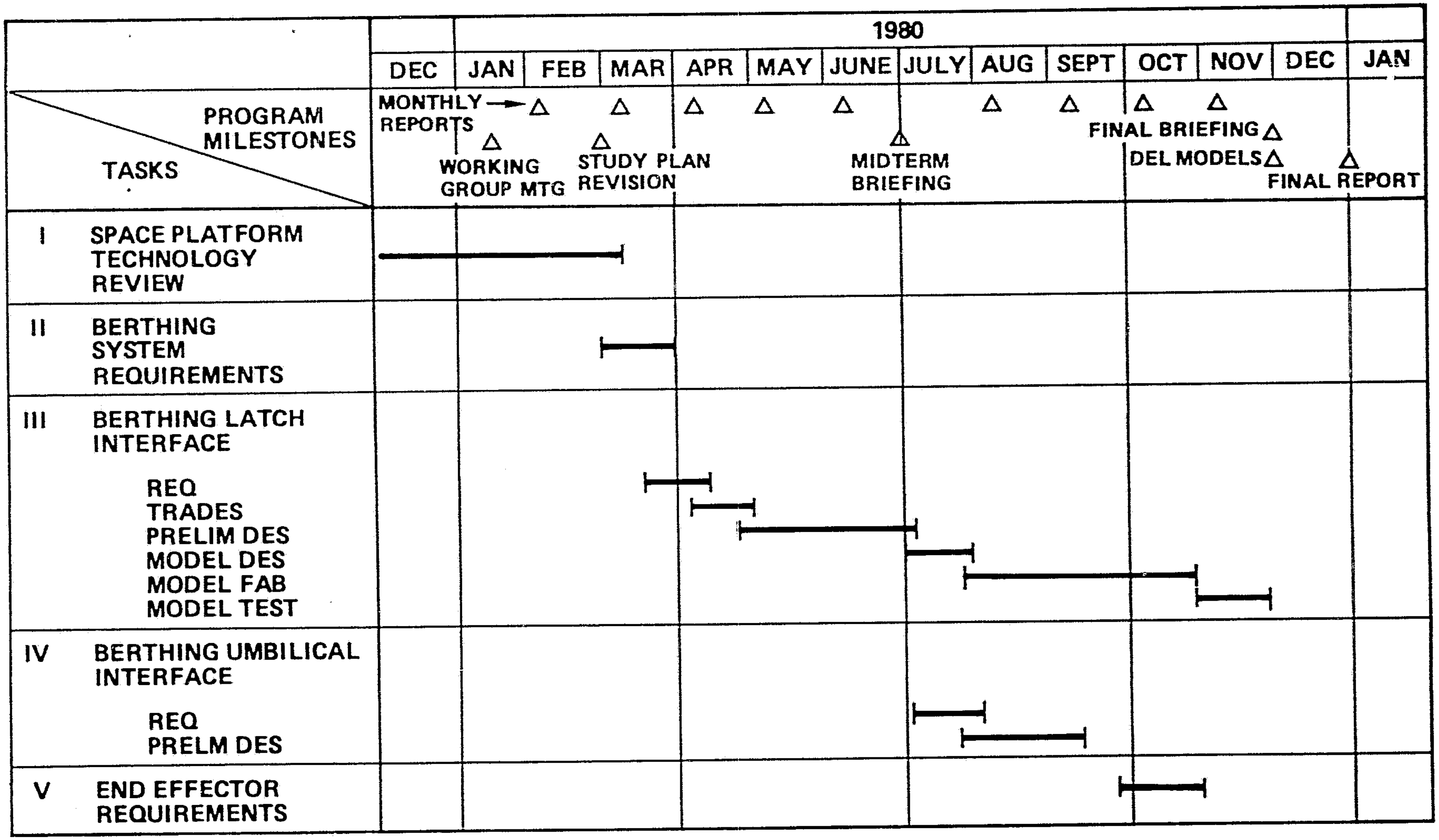


Figure 2. Space Platfrom ADV Tech Study Schedule

Section 5

MANAGEMENT APPROACH

This study will be performed in the Advanced Space Program Directorate in the McDonnell Douglas Astronautics Company - Huntington Beach. This organization consists of personnel with project systems discipline and engineering personnel in one location dedicated specifically to space systems.

The study will report to George Butler, Director of Advanced Space Concepts and will benefit from the ongoing Conceptual Design Study for a Science and Applications Space Platform (SASP) being conducted for NASA-MSFC. The study organization is shown in Figure 3.

Established study management principles will be applied to ensure direction and control of study effort. Management emphasis will be placed on ensuring rapid and coordinated reaction to possible changes in program direction, and on prompt response to NASA-JSC requests for special data or information.

Features of our management approach include:

- Integrated co-located team
- All resources controlled by the Study Manager
- Proven team with Space Systems background
- Study team accessible to NASA-JSC
- Study tasks planned to enable NASA concurrence on reference design accommodation of updated payload requirements.

- **Study tasks fully defined to simplify work direction, visibility and control**
- **Related NASA contracted work to provide maximum contribution to study objectives**

This study will be managed by Mr. Gene C. Burns. He will be assisted by Mr. George King, Mr. Ned Taniguchi and Mr. Dirck Hartmann who are responsible for configuration, mechanical design and structural design, respectively. Mr. Burns will also manage the Interfaces and Requirements tasks.

Mr. Burns will direct all study activities and control all study resources. His responsibilities include all management activities related to work planning and authorization, technical performance assessment and reporting.

Each task manager will direct all activity specifically related to his task. He will establish requirements for work to be performed and will coordinate the effort and integrate results to assure study objectives are met in a timely manner.

SUPPLEMENT TO

SPACE PLATFORM ADVANCED TECHNOLOGY STUDY PLAN

March 1980

SUPPLEMENT TO SPACE PLATFORM

ADVANCED TECHNOLOGY STUDY PLAN

Introduction

The basic Space Platform Advanced Technology Study consists of five tasks to further design definition in specific mechanical design areas. Task V of the plan establishes requirements for an end effector to be used with the RMS in conjunction with assembly deployment and maintenance of space platforms and payloads. This supplement adds a sixth task to the study which will utilize the requirements derived in Task V to prepare designs and fabricate a model of the end effector.

The basic study schedules Task V late in the program to level manpower requirements. If Task VI is added it will be necessary to reschedule Task V earlier to allow the design and model work to be accomplished within the same period of performance as the basic program. The revised schedule is shown in Figure 1.

Task VI represents a contract funding increase of $50,000. This funding would be devided approximately evenly between engineering manhours for design and model fabrication and test.

Task VI

Objectives

The objectives of this task are:

- Prepare design and details for demonstration model
- Fabricate demonstration model
- Demonstrate feasibility of design

Approach

Using the requirements derived in Task V, an end effector design will be prepared in sufficient detail to fabricate a demonstration model of the mechanism. The model will be used to demonstrate function when used in conjunction with the NASA RMS simulator.

Rationale

This task represents a logical follow-on extension to Task V of the basic study. The selection and modeling of a design will represent a technology advance toward the development of a required tool for the space platform.

Task Output

- End effector design
- End effector demonstration model

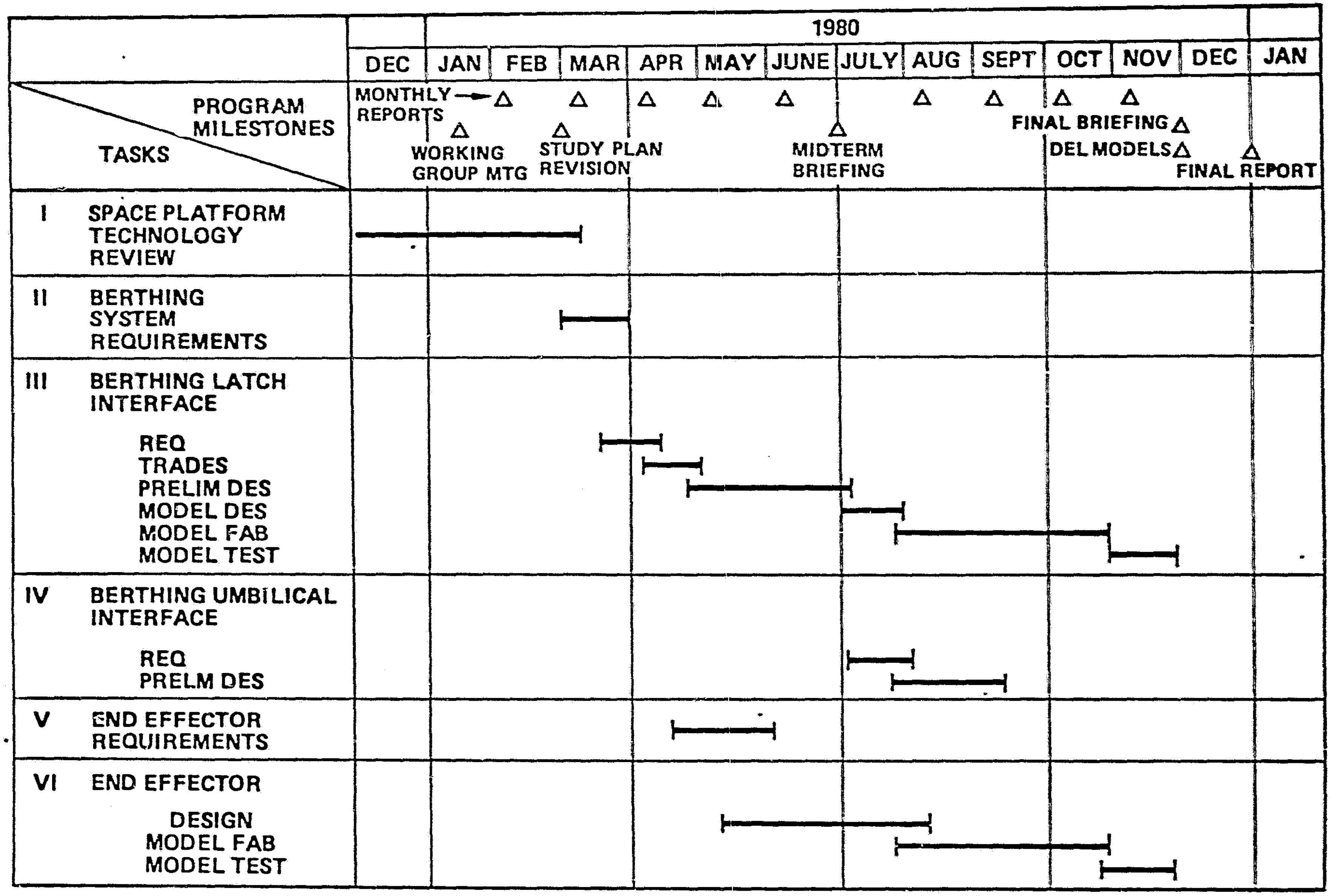


Figure 1. Space Platform ADV Tech Study Schedule